Series II, Volume 3 August 26, 1958 Number 5

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

INCLUDING THE

PROGRAMME OF THE

1958 SUMMER MEETING IN THE WEST

AT THE

UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER

August 26, 27, and 28

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY, COLUMBIA UNIVERSITY, NEW YORK 27, NEW YORK
EIGHT ISSUES EACH YEAR

BULLETIN

of the

AMERICAN PHYSICAL SOCIETY

Published eight times per year

Subscription price: $5.00 per year

Single copies: $1.00 each

The Bulletin of the American Physical Society is published eight times a year, once in January, once in March, once in May, once in June, once in August, once in September, once in November, and once in December, at Prince and Lemon Streets, Lancaster, Pennsylvania. Correspondence should be addressed to American Physical Society, Columbia University, New York 27, New York.

Entered as second class matter, December 27, 1949, at the post office at Lancaster, Pa., under the Act of August 24, 1912.

Acceptance for mailing at a special rate of postage provided for in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized Nov. 30, 1948.

Table of Contents

1958 summer meeting at the University of British Columbia, Vancouver:
Preamble 312
Epitome 314
Programme 315
Index 341
Reservation form 343
Second announcement of 1958 Thanksgiving Meeting 345
Preliminary announcement of 1958 Winter Meeting in West 345
Preliminary announcement of 1959 Annual Meeting 345
Announcement of 1958 Meeting of Division of Fluid Dynamics 345
Calendar of 1958–1959 Meetings and Deadlines 346
Rules and instructions for the preparation of abstracts 346
Report of the Nominating Committee 347
Eligibility and Election to Fellowship 347
Minutes of the 1958 Spring Meeting at Washington, D. C., May 1–3, 1958 348
Minutes of the Spring Meeting of the Ohio Section at Akron, Ohio, April 11–12, 1958 349

August 26, 1958 Series II, Vol. 3, No. 5

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

1958 Summer Meeting in the West, University of British Columbia, Vancouver, August 26–28, 1958

THE **1958 summer meeting** on the Pacific Coast will be held on the campus of the University of British Columbia, Vancouver, Canada, on Tuesday, Wednesday, and Thursday, **August 26, 27, and 28.** All the sessions but one will be held in the Physics Building. The exception will be Session P in Engineering 201. The Society is meeting in Vancouver in celebration of the Centenary of the foundation of the Province of British Columbia and in honor of the University's fiftieth anniversary.

Accomodations will be available on campus in Women's Residences at $3.00 per night per person in double rooms. At the time of distribution of this Bulletin, rooms may no longer be available at the Fort Camp men's temporary dormitories. These accomodations are suitable for families with children, and the rate is about $2.00 per person per night. Hotels in downtown Vancouver include the Hotel Vancouver (from $8.00 single, $10.50 double, $12.50 twin beds), Hotel Georgia (from $7.00 single, $10.00 double, $11.00 twin beds), and Hotel Devonshire (from $9.50 double, $10.50 twin beds). The most conveniently situated motels are those downtown, the Burrard Motel, Kamlo Motor Apartment Motel, Park Town Motel, and Downtowner Motel. The majority of the motels, however, are located along Kingsway on the southern approach to the city along Route 1/99 between New Westminster and Vancouver at 9 to 15 miles from the campus. Write to Dr. Pickard if you need a list of addresses. Reservations for campus accomodations should be addressed to Dr. G. L. Pickard, A.P.S. Local Arrangements Committee, Department of Physics, University of British Columbia, Vancouver 8, B. C., Canada.

Because of excessive comment about the notice of accomodations for private yachts that appeared in the Preliminary Announcement for the meeting, travel advice will not be repeated and the prospective attendee is referred to that announcement.

Those who will be staying on campus can have their **meals,** cafeteria style, at the Fort Camp dining room which is near the Women's Residences and the Fort Camp Dormitory. The schedule is: Breakfast 7:30–8:30 A.M., Lunch 12:00–1:00 P.M., Supper 5:00–6:00 P.M. Those who will be staying off campus may have lunch at the Faculty Club. This is as good a place as any to remind all that British Columbia is on Pacific Daylight Time.

Registration, including accomodations, the banquet, cruise, and other information, will be at a desk in the Physics Building. The usual charge of $1.00 will be in force. The desk will be staffed from 4:00 to 9:00 P.M. on the Monday before the meeting and from 8:30 A.M., on, during the meeting days. This is perhaps the time to mention that, while the registration fee will be satisfied with either American dollars or Canadian, very little else will be, since there is a slight premium on the Canadian dollar.

Tickets for the banquet of the society will be sold at the registration desk. The price is $3.25 per person. The dinner will be held at 7:00 P.M. Wednesday evening in the Brock Memorial Building. Those who enjoy going to the banquet are urged to send in their reservations on the form for this purpose included in this Bulletin, and they will be held until 1:00 P.M. Wednesday. This is important, since the Society Banquet was oversubscribed at the last three meetings on the West Coast. We are fortunate in that our principal speaker will be Professor Denys H. Wilkinson of Oxford University.

The programme consists of **139 contributed papers** and **27 invited papers.** This is the first time that it has been necessary to have four sessions in parallel at a summer meeting. There are also three undesirable and unavoidable conflicts in the programme. The programme was arranged with the aid of the local committee, and we are especially grateful to Dr. J. B. Warren.

There are a number of events that have been arranged for members and guests of the Society. There will be a **cruise** on Tuesday evening aboard an oceanographic vessel. Registration for this cruise can be made at the desk. However, space is severely limited and, since a primary purpose is the demonstration of scientific equipment, children will be discouraged from attending. There will be a show of **Canadian films** in the Brock lounge on the same evening for those who will not be on the cruise. A **Ladies' Programme** is being arranged. It will include a bus tour, tickets for which can be obtained at the ladies' desk. The trip to **Garibaldi Park,** details of which are in the Preliminary Announcement, is still on for those who are staying on after the meeting.

Tea. The University of British Columbia will be host to the Society at a tea in the quadrangle of the Buchanan Building from 4:30 to 5:30 P.M. on Wednesday, August 27.

Post-deadline papers of sufficient importance to warrant their inclusion in a special supplementary program will be considered by the Local Secretary if the abstracts are received no later than Tuesday, August 19, at the office of the Local Secretary for the Pacific Coast (see address below). These papers will be presented following sessions that will be designated on a blackboard near the registration desk in the Physics Building.

Errata will be published in a later issue of this Bulletin if received not later than Monday, September 8, at the office of Miss Ruth Bryans, American Institute of Physics, 335 East 45th Street, New York 17, New York. Do not send your abstract defaced with corrections: write out the corrections in the form "Instead of . . . read. . . ." Do not add anything. Errata are not published either for introducing new data, or for restoring material that was cut out because the abstract was too long.

W. A. NIERENBERG,
Local Secretary for the Pacific Coast
Department of Physics
University of California
Berkeley 4, Californa

EPITOME OF THE 1958 SUMMER MEETING IN THE WEST AT THE UNIVERSITY OF BRITISH COLUMBIA

(Personal names are those of invited speakers.)

Tuesday Morning

9:00 A. Plasma physics; Thompson, Christofilos. Physics 200.

10:30 B. Low-energy nuclear physics I; Wilkinson. Physics 201.

10:30 C. Theory. Physics 202.

Tuesday Afternoon

2:00 D. Low-energy nuclear physics; Christy, Fleischmann, Tobocman, Brockhouse. Physics 200.

2:00 E. Resonance physics I. Physics 202.

2:00 F. Spectroscopy; Shenstone. Physics 201.

Wednesday Morning

9:30 G. High-energy physics; Cork, Dalitz, McDaniel, Woodward, Steinberger. Physics 200.

9:30 H. Low-energy nuclear physics II. Physics 201.

9:30 I. Resonance physics II. Physics 202.

Wednesday Afternoon

2:00 J. Earth and cosmic physics; Gordon, Struve, Forsyth. Physics 200.

1:30 K. Low-energy nuclear physics III; Lauritsen. Physics 201.

1:30 L. Solid-state physics. Physics 202.

Wednesday Evening

7:00 Banquet of the American Physical Society; Wilkinson. Brock Memorial Building.

Thursday Morning

9:30 M. Resonance and low-temperature physics; Lew, Fairbank, Wheatley, Redfield. Physics 200.

9:30 N. Low-energy nuclear physics IV; Williams. Physics 201.

9:30 O. Geophysics; Phillips. Physics 202.

9:00 P. High-energy physics. Engineering 201.

Thursday Afternoon

1:30 Q. Solid-state physics; Garlick, Bloembergen, Norberg, Lax. Physics 200.

1:30 R. Low-energy nuclear physics V. Physics 201.

2:00 S. Low-temperature physics. Physics 202.

PROGRAMME

TUESDAY MORNING AT 9:00

Physics 200

(S. A. ALLISON, presiding)

Invited Papers on Plasma Physics

A1. Recent Plasma Research at Harwell. WILLIAM B. THOMPSON, *A.E.R.E., Harwell, United Kingdom* (40 min.)

A2. The Astron Thermonuclear Device. NICHOLAS C. CHRISTOFILOS, *University of California Radiation Laboratory, Livermore.* (30 min.)

TUESDAY MORNING AT 10:30

Physics 201

(J. B. WARREN presiding)

Low-Energy Nuclear Physics I

Invited Paper

B1. Nuclear Photodisintegration. DENYS H. WILKINSON, *Oxford University.* (30 min.)

Contributed Papers

B2. Decay of As^{74}.*† D. J. HOREN AND D. O. WELLS, *Stanford University.*—The decay of As^{74} has been reinvestigated using scintillation spectrometers. In addition to the previously known annihilation quanta and gamma rays of 0.596 and 0.635 Mev,[1] the singles spectrum shows gamma rays of 1.19±0.01, 1.60±0.04, and 2.22±0.02 Mev. The 1.19-Mev gamma ray was found to be in coincidence with GeK x-rays and is believed to arise from the decay of a second excited state at this energy in Ge^{74} as postulated by Sinclair.[2] Additional evidence for this assignment was obtained from gamma-gamma coincidence measurements. The 2.22-Mev gamma ray presumably arises from the decay of a level at this energy in Ge^{74}. A tentative decay scheme will be presented.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
† The preliminary work was performed by E. Brun, J. J. Kraushaar, W. E. Meyerhof, D. J. Horen, and J. E. Neighbor, III.
[1] Johansson, Cauchois, and Siegbahn, Phys. Rev. **82**, 275 (1951).
[2] Rolf M. Sinclair, Phys. Rev. **107**, 1306 (1957).

B3. Gamma Rays from $(p,p'\gamma)$ and $(p,n\gamma)$ Reactions.* E. L. CHUPP, J. W. M. DUMOND,† F. J. GORDON, R. C. JOPSON, AND HANS MARK,‡ *University of California Radiation Laboratory, Livermore.*—The gamma rays following $(p,p'\gamma)$ and $(p,n\gamma)$ reactions in seven isotopes have been studied with a bent-quartz-crystal spectrograph. The intense gamma-ray sources necessary for such experiments were provided by bombarding various target materials with large proton beam currents from the A-48 accelerator. The following reactions and associated gamma rays have been observed: $F^{19}(p,p'\gamma)$, 109.87±0.04 kev; $Ti^{49}(p,n\gamma)V^{49}$, 90.65±0.02 kev, 62.29±0.01 kev; $Mn^{55}(p,p'\gamma)$, 125.87±0.05 kev; $Ni^{61}(p,p'\gamma)$, 67.40±0.01 kev; $Cu^{65}(p,n\gamma)Zn^{65}$, 53.93±0.01 kev, 61.20±0.01 kev, 115.09±0.04 kev; $Ge^{73}(p,p'\gamma)$, 67.03±0.01 kev; and $Se^{80}(p,n\gamma)Br^{80}$ 37.05±0.01 kev.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
† At California Institute of Technology.
‡ Now at MIT.

B4. Energy Levels of Ru^{102} Appearing in the Decay of Rh^{102}.* KAZUO HISATAKE† AND J. D. KURBATOV, *The Ohio State University.*—Enriched ruthenium-102 was activated in the University of Washington cyclotron. After purification and separation of rhodium-102 the excited states of ruthenium-102 were determined in the decay of rhodium-102. The energy levels are 0.475, 1.106, 1.565, 1.875, and 2.255 Mev. The angular momenta and parities of the ground and first excited states are 0+ and 2+, respectively, as is well known. The angular momenta of the second and third excited states were assigned the value of 2 in both cases from the gamma-gamma angular correlation measurements. The decay scheme, which will be presented, was determined from gamma-gamma and beta-gamma coincidence measurements. The parities of the energy levels were obtained from the *ft* value of each transition and all were even except probably for the 2.255-Mev level. The levels of even parity are considered to be quadrupole oscillation levels. The angular momentum and parity of the ground state of rhodium-102 was determined from the partial ft values of the decay.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
† Now at Institute of Technology, O-Kayama, Merguro-Ku, Tokyo, Japan.

B5. Decay of Short-Lived Barium and Lanthanum Fission Products.* R. P. SCHUMAN, E. H. TURK, AND R. L. HEATH, *Phillips Petroleum Company, Atomic Energy Division.*—Fission product barium samples were chemically isolated from neutron irradiated U^{235}. Lanthanum samples were milked from the purified barium fractions after suitable decay periods. Half-lives were determined by following gross beta decay and decay of the individual gamma rays. The half-lives of the barium samples were also obtained by periodic milking of lanthanum daughters. The measured half-lives are: 11±1 min for Ba^{142}, 18±1 min for Ba^{141}, 85±6 min for La^{140}, and 231±6 min for La^{142}. Single crystal gamma-ray spectra were determined with a 3 by 3 in. NaI(Tl) scintillation spectrometer.

Prominant gamma rays are observed at 0.08, 0.90, 1.09. 1.21, 1.36, and 1.67 Mev for Ba^{142}; 0.20, 0.29, and 0.46 Mev for Ba^{141}; a weak gamma at 1.37 Mev for La^{141}; and 0.645, 0.90, 1.03, 1.37, 1.54, 1.75, 1.92, 2.08, 2.40, 2.55. 2.97, 3.30, and 3.60 Mev for La^{142}. Gamma-gamma coincidence spectra were measured for La^{142}. Beta spectra were measured on the lanthanum samples with an anthracene crystal spectometer. The most energetic beta from the decay of La^{142} has an energy of ~4 Mev.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

B6. Decay of Rh^{105}.* A. ROSEN, *University of Southern California* (introduced by H. H. Forster).—The radioactive decay of $Rh^{105} \rightarrow Pd^{105}$ has been investigated with a double thin lens beta-ray spectrometer and single crystal and coincidence scintillation spectrometers. The source material was powdered metallic ruthenium irradiated at the Chalk River pile. Sources were prepared by either dissolving the powder in sodium hypochlorite solution or evaporating it onto thin aluminum foils. A Fermi analysis of the beta spectrum showed evidence for the existence of two beta groups of end-point energies 560±20 kev and 265±20 kev, respectively. However, the existence of a third beta group of end-point energy 420±70 kev could not be ruled out. Photoelectron spectra obtained through internal and external conversion established gamma rays of energy 220±5 kev, 315±3 kev, and 415±3 kev. In addition, gamma rays of 308±5 kev and 550±10 kev were found through gamma-gamma coincidences, which also showed that the 220, 308, 415, and 550 kev gammas were in coincidence with the 215-kev gamma ray. No coincidences between the 220- and 415-kev gamma could be observed. Beta-gamma coincidences showed that the beta groups of 560, 420, and 265 kev were in coincidence with gamma rays of 315, 220, and 308 kev, respectively.

* This work has been supported in part by the Office of Naval Research.

B7. Coincidence Studies of B^{12} and F^{20}.* R. W. KAVANAGH, *California Institute of Technology.*—Using scintillation counters and a pulsed beam from an electrostatic accelerator, a search has been made for γ rays from the 7.65-Mev α-emitting[1] level of C^{13} following β decay of B^{12} made via the reaction $B^{11}(d,p)B^{12}$. Limits found are $\gamma_{3.2}/\gamma_{4.4}<0.1\%$ and $\gamma_{7.6}/\gamma_{4.4}<0.2\%$. A similar search for γ-γ coincidences from the 4.97-Mev γ-emitting[2] level of Ne^{20} sought in the β decay of F^{20} resulted in the limit $\gamma_{3.3}/\gamma_{1.6}<0.03\%$, indicating log $ft>6.5$ for the corresponding β transition. The consequences for the proposed stellar reactions $Be^9+\alpha$ and $O^{16}+\alpha$ will be discussed.

* Supported in part by the joint program of the U. S. Atomic Energy Commission and the Office of Naval Research.

[1] Cook, Fowler, Lauritsen, and Lauritsen, Phys. Rev. **107**, 508 (1957).
[2] Gove, Litherland, and Ferguson, Bull. Am. Phys. Soc. Ser. II, **3**, 36 (1958).

TUESDAY MORNING AT 10:30

Physics 202

(F. A. KAEMPFFER presiding)

Theory

C1. Generation of Magnetohydrodynamic Waves in a Compressible Dissipationless Fluid. L. C. LEVITT, *Hughes Research Laboratories.*—A study is presented of the small-amplitude magnetohydrodynamic radiation generated by a point body force in an unbounded, nonviscous, perfectly-conducting fluid permeated by a uniform magnetic field. The relevant linearized vector wave equation is treated by Fourier transform methods, utilizing the stationary-phase approximation. The forms of the wave fronts of the three emitted modes (characteristic surfaces of the differential equation) are exhibited. Expressions are derived, asymptotically exact at large distances for a sinusoidally oscillating source, from which one may readily compute the velocity field in the wave zone for each of the three modes. Formulas are also found for the angular distribution of the power radiated into each mode by an extended driving source. Certain striking anomalies, arising partly from the stationary-phase approximation and partly from the assumption of a dissipationless fluid, are pointed out and discussed.

C2. Diamagnetism of an Electron Gas.* R. V. HANKS AND I. OPPENHEIM, *National Bureau of Standards.*—The diamagnetic susceptibility of an electron gas is computed using techniques similar to those of Montroll and Ward.[1] Results are obtained for the ideal Boltzmann and Fermi Dirac gases without an explicit and somewhat forced use of boundary conditions. Results for the interacting Boltzmann and Fermi Dirac gases are obtained for high temperature, low density, and for low temperature, high density systems by a summation over ring cluster integrals. The effects of the magnetic field are taken into account exactly by use of the temperature analog of the Feynman propagator for a charged particle in a magnetic field.

* Supported in part by the U. S. Atomic Energy Commission, Division of of Research.

[1] E. Montroll and J. Ward, Phys. Fluids 1, 55 (1958).

C3. Quantum Statistics of Fermi Gases.* FRANZ MOHLING AND BORIS A. JACOBSOHN, *University of Washington.*—The binary collision expansion method (BCEM) is studied for low-temperature systems of particles with shortrange forces. The sum over all single-particle clusters is performed. After suitable rearrangements the grand potential for a Fermi gas is expressed in terms of the two-particle scattering matrix. Whereas many terms in the original formulation of the BCEM diverge in the low-temperature limit, the rearranged expression for the grand potential contains only convergent terms. It is shown that, up to and including third-order terms in the ratio ($\rho^{\frac{1}{3}}\times$interaction range), the energy of a Fermi gas depends on three scattering parameters: the scattering length (a_s) and effective range for S waves, and the P-wave scattering length. This result is in agreement with the predictions of the pseudopotential method. The fourth-order terms are shown to involve the scattering matrix off the energy shell, and are therefore not correctly given by the pseudopotential method. The leading term in the high-energy tail of the momentum distribution of a Fermi gas (spin$=J$) is found to be $2J(2J+1)[(2/3\pi)k_F a_s]^2(k_F/k)^4$. A second problem which is examined is that of a system of fermions.

* This work was supported in part by the U. S. Atomic Energy Commission.

C4. Limit on the Validity of Strømer Theory for Clouds of Particles. PAUL J. KELLOGG, *University of Minnesota.*—If an

ionized cloud approaching the earth is sufficiently rare the particles will follow the orbits of Størmer theory. We have investigated the density for which interparticle interactions become important. If the particles in the cloud obey Størmer theory, then the protons (or positive ions) will approach much closer to the earth than the electrons. Therefore, a large region of space will contain only protons. The electrons will follow Størmer orbits if the potential of this charged region at its outer surface is small compared to the electron energy. Thus the electrons will obey Størmer theory if $n \ll (\frac{1}{4}\pi)(E_e/e^2)(1/l^2)$ where E_e is the initial energy of the electrons, l is the Størmer radius for electrons, and n is the ion density. This is more stringent than the criterion of Chapman and Ferraro[1] by a factor of β^2 for reasons which will be discussed. The criterion for the protons to follow Størmer orbits is more complicated since they are less effected by the electric field. It is necessary to use Størmer's theory[2] of the behavior of charged particles in a magnetic dipole plus electric monopole field (suitably modified for relativistic effects) to find the region from which electrons are excluded. Results will be presented in numerical form.

[1] Chapman and Ferraro, Terr. Mag. 45, 245 (1940).
[2] C. Størmer, *The Polar Aurora* (Oxford University Press, New York, 1955).

C5. Modified Propagators in Field Theory. P. J. REDMOND,* *Physics Department, University of California, Berkeley, California,* AND J. L. URETSKY,† *Radiation Laboratory, University of California, Berkeley, California.*—It was observed by Brueckner *et al.*[1] that strong pair damping could be achieved in *ps-ps* meson theory by making use of renormalized propagators in which certain "primitive" diagrams were summed to all orders. Feldman,[2] attempting to use such propagators in calculations, noted that they contained nonphysical poles corresponding to "ghosts." One of us (P. J. R.) has observed that it is possible to surmount the "ghost" difficulty by assuming the validuty of a mass-spectral representation.[3] The inaginary part of the modified propagator then provides a first approximation for the spectral functions. Expressions obtained in this way for the meson and nucleon propagators will be given. It is found that the wave-function renormalization is finite.

* Supported in part by the Office of Ordnance Research, United States Army.
† Supported by United States Atomic Energy Commission.
[1] Brueckner, Gell-Mann, and Goldberger, Phys. Rev. **90**, 476 (1953).
[2] G. Feldman, Proc. Roy. Soc. (London) **A223**, 112 (1954).
[3] Lehmann, Symanzik, and Zimmermann, Nuovo cimento **1**, 205 (1955).

C6. Some Considerations on the Gravitational Mass of Antimatter. D. MATZ AND F. A. KAEMPFFER, *University of British Columbia.*—Morrison and Gold[1] have suggested that antimatter may have negative gravitational mass. In a universe consisting of equal amounts of matter and antimatter the average gravitational field is then produced essentially by the positive contribution from the kinetic energy density of both matter and antimatter. Solutions of correspondingly modified equations of classical cosmology have been investigated. It appears that the hypothesis of Morrison and Gold cannot be excluded on the basis of observational evidence.

[1] P. Morrison and T. Gold (private print, 1956).

C7. Poisson Brackets in Field Theory. HANS FREISTADT, *The University of British Columbia.*—Several covariant schemes for defining classical and quantum Poisson brackets for field variables are considered. The approach of Good[1] rather than that of Bergmann[2] is followed. A formalism based on the use of a tensor Hamiltonian, similar to a formalism proposed earlier,[3] can be derived from a variational principle involving a tensor Lagrangian; but the definition of classical Poisson brackets is cumbersome in this formalism. The best procedure is probably the obvious generalization of the formalism of Good,[1] although the definition of quantum Poisson brackets is somewhat artificial.

[1] R. H. Good, Jr., Phys. Rev. **93**, 239 (1954).
[2] P. G. Bergmann and J. H. M. Brunings, Revs. Modern Phys. **21**, 480 (1949).
[3] H. Freistadt, Bull. Am. Phys. Soc. Ser. II, **2**, 143 (1957).

TUESDAY AFTERNOON AT 2:00

Physics 200

(M. E. ROSE presiding)

Invited Papers on Low-Energy Nuclear Physics

D1. Capture Reactions in Light Nuclei. ROBERT F. CHRISTY, *California Institute of Technology.* (30 min.)

D2. Methods to Produce Polarized Protons. RUDOLF FLEISCHMANN, *Physikalische Inst. der Univ. Erlangen, Germany.* (30 min.)

D3. Numerical Evaluation of Stripping Cross Sections and Polarizations. WILLIAM TOBOCMAN, *Rice Institute.* (30 min.)

D4. Crystal and Liquid Dynamics by Neutron Spectrometry. BERTRAM N. BROCKHOUSE, *Atomic Energy of Canada Ltd.* (30 min.)

TUESDAY AFTERNOON AT 2:00

Physics 202

(J. C. HUBBS presiding)

Resonance Physics I

E1. Spin-Spin Interactions in Potassium Cobalti-Chromicyanide. S. SHAPIRO, N. BLOEMBERGEN, AND J. O. ARTMAN, *Harvard University.*—In order to study energy exchange between neighboring spin resonances at 4.2°K, a small single crystal of $K_3(99.5\%\ Co,\ 0.5\%\ Cr)\ (CN)_6$ has been used in the Harvard *L*-band maser cavity.[1] The resonances resulting

from the two nonequivalent Cr^{3+} sites in unit cell could be split by varying the orientation of the steady magnetic field in the crystallographic *ab* plane. If by pumping ion *B* at *X* band the *L*-band resonance of ion *B* was made emissive, then it was found that the neighboring resonance of ion *A* at *L* band (50 Mc/sec away) became emissive. Saturation curves at *X* band for both ions *A* and *B* (200 Mc/sec apart) were taken at the same magnetic field by changing the cavity resonant frequency. The data rule out the possibility that the observed effect was due to a direct maser effect on ion *A* as a result of cross saturation at *X* band. The results contradict the assumption[2] that equilibrium between spin levels is established through the intermediary of phonons because phonons cannot transfer an emissive condition. They are consistent with the hypothesis that equilibrium between spin levels is established through spin-spin interactions between resonances with overlapping tails. Theoretical expressions for spin-spin interactions between adjacent resonances are being tested by further experiments.

[1] Artman, Bloembergen, and Shapiro, Phys. Rev. **109**, 1392 (1958).
[2] Giordmaine, Alsop, Nash, and Townes, Phys. Rev. **109**, 302 (1958).

E2. Electron Paramagentic Resonance of Photosensitive Radicals in Organic Solids. L. A. WEBB, AND R. S. ALGER, *U. S. Navy Radiological Defense Laboratory, San Francisco, California.*—The reported[1] photosensitivity of paramagnetic species responsible for the EPR hf structure observed in x-irradiated solid methanol and ethanol has been examined further. Samples of alcohols containing about 1% of such uv-sensitive compounds as Wurster's blue, H_2O_2, or NaOCl were irradiated at −196°C with selected wavelengths of uv from an AH-6 mercury arc. Irradiation of methanol at 3100 A produces the triplet reported by Gibson *et al.*[2] This triplet is similar to the x-ray induced hf structure except that the splitting is about 3 gauss wider and the central peak lower, which is additional evidence of an underlying species in the x-irradiated material. The quintet in ethanol follows a similar pattern. Irradiation of the methanol samples at 2537 A converts both the uv- and the x-ray induced triplets into a doublet with a splitting of 129 gauss. The doublet has been produced similarly in numerous other materials all of which contain the CH_3O-group, such as CH_3OD, methyl esters, and methyl ethers, but not in ethanol, CD_3OH, sodium methoxide, anisole, methyl mercaptan, or the methyl sulfides.

[1] L. A. Webb and R. S. Alger, Bull. Am. Phys. Soc. Ser. II, **2**, 372 (1957).
[2] Gibson, Ingram, Symons, and Townsend, Trans. Faraday Soc. **53**, Part 7, 914 (1957).

E3. Frequency Dependence of the Nuclear Spin-Lattice Relaxation.* EDWIN A. UEHLING AND JOHN L. BJORKSTAM, *University of Washington.*—The relaxation time T_1 of spin ½ nuclei in certain crystals of KH_2PO_4 and KH_2AsO_4 is linearly dependent on frequency over a wide range of frequencies.[1] In one case studied so far the ratio of the frequency coefficients for different nuclei in the same crystal has been obtained. In our crystal of KH_2PO_4 the relaxation time increases at the rate of 0.5 sec per Mc/sec for the protons and 6.0 sec per Mc/sec for the phosphorus. A semiquantitative explanation of the observed facts can be given if we make the following assumptions: (a) relaxation is due to the presence of a small density of paramagnetic ions as first proposed by Bloembergen[2]; (b) the thermal relaxation time T_{1e} of the paramagnetic ions fulfills the condition $T_{1e} \ll 1/\nu_0$ for the smallest nuclear resonance frequency ν_0 in our experiments. Under these conditions the effective volume of the region surrounding the paramagnetic ion into which spin energy must be transported by diffusion varies inversely as the frequency. Numerical analysis is required in order to explain the dependence of the frequency coefficient on the gyromagnetic ratios and crystal structure.

* Supported in part by the Air Force Office of Scientific Research.
[1] J. L. Bjorkstam and E. A. Uehling, Bull. Am. Phys. Soc. Ser. II, **3**, 166 (1958).
[2] N. Bloembergen, Physica **15**, 386 (1949).

E4. Nuclear Magnetic Relaxation Induced by *F*-Center Electrons.* W. E. BLUMBERG AND E. L. HAHN, *University of California, Berkeley.*—Nuclear magnetic relaxation has been studied as a function of Larmor precession frequency for Na^{23} nuclei in pure (Harshaw optical quality) NaCl and NaCl which contained about 10^{18} *F* centers per cm^3. The relaxation time at 10 Mcps is 12 seconds for both samples, indicating that the *F* centers are not an effective relaxation mechanism at this frequency. The relaxation in the pure NaCl does not change with frequency above about 10 kcps, below which spin exchange with the Cl nuclei takes place. The relaxation in the crystal with *F* centers, on the other hand, shows a strong relaxation mechanism below about 125 kcps, producing an additional transition probability of 0.13 sec^{-1}. This mechanism is attributed to the I_+S_+ interaction of the electron and the nuclear moments instead of the usual paramagnetic impurity relaxation mechanism. The power spectrum has the Lorentz shape characteristic of a Markoff relaxation process. The half power width is 125 kcps, giving a spin-lattice relaxation time of 1.3 μsec for the electron.

* Supported in part by the U. S. Office of Naval Research and the U. S. National Security Agency.

E5. Pure Quadrupole Resonance in $RbClO_3$ and $CsClO_3$.* M. EMSHWILLER AND E. L. HAHN, *University of California.*—By use of a pulsed oscillator ganged to a two-stages tuned preamplifier followed by a wide band amplifier and a selected time integration circuit (based on the "box-car" design[1]), we have sucessfully searched for chlorine spin echoes[2] due to pure quadrupole resonance in powdered $RbClO_3$ and $CsClO_3$. The respective frequencies are 28.81 Mc and 28.37 Mc. The echo technique allows for identification of the quadrupole resonance, in spite of strong piezoelectric transients of wide frequency range following each pulse. Using the chlorine echo as an indicator, a search is being conducted by means of the three-pulse double-resonance method[3] for rubidium and cesium resonance. If the alkali nuclei undergo a transition about the same time as the second pulse is applied to the chlorine system, then the chlorine echo will be degraded. A rubidium transition has been found at 3.22 Mc with a line width of 0.06 Mc. Further search is being conducted for the other two lines possible.

* Supported in part by the U. S. Office of Naval Research and the U. S. National Security Agency.
[1] D. F. Holcomb and R. E. Norberg, Phys. Rev. **98**, 1074 (1955).
[2] Bloom, Hahn, and Herzog, Phys. Rev. **97**, 1699 (1955).
[3] D. Kaplan and E. L. Hahn, Bull. Am. Phys. Soc. II, **2**, 384 (1957).

E6. Nuclear Spin of Bromine-76.* T. M. GREEN, H. L. GARVIN, AND E. LIPWORTH, *University of California Radiation Laboratory, Berkeley.*—As part of a continuing program of investigation of the nuclear constants of the radioactive halogens, the nuclear spin of 17.5-hr bromine-76 has been measured by the method of atomic beams. Bromine-76 was produced by an $(\alpha,3n)$ reaction on arsenic powder which was bombarded on the Berkeley 60-in. cyclotron with 48-Mev alpha particles. The active material was separated from the target and mixed with natural carrier, and an atomic beam was formed in a discharge tube. The beam was collected on silver-coated buttons and counted in continuous-flow beta counters. The electronic ground state of bromine is $^2P_{\frac{3}{2}}$. Both of the allowed "flop-in" transitions in this ground state have been observed at magnetic fields of 3.99, 7.98, and 15.95 gauss. All these resonances are consistent with an assignment of 1 for the nuclear spin of bromine-76. The isotope has been

identified on the basis of its decay properties. Work is under way to measure the hyperfine separations of bromine-76.

* Done under the auspices of the U. S. Atomic Energy Commission.

E7. Zeeman Investigations of Curium-242.* R. MARRUS, J. C. HUBBS, AND J. WINOCUR, *Radiation Laboratory and Department of Physics, University of California, Berkeley.*—The atomic-beam magnetic-resonance method has been used to investigate 163-day Cm^{242} in the Zeeman region of optical and hyperfine-structure spectroscopy. The magnetic moment of this even-even nuclide is found to be less than 2×10^{-4} cm on the basis of calculated electronic matrix elements. The spin of Cm^{242} is therefore probably 0. Four low-lying electronic energy levels are found, with $g_{J_1}=2.561\pm0.003$, $g_{J_2}=2.000\pm0.002$, $g_{J_3}=1.776\pm0.002$, and $g_{J_4}=1.671\pm0.003$. The observed g values are those calculated for two weakly interacting systems $J_1=\frac{1}{2}$, $g_{J_1}=2.001$, and $J_2=\frac{1}{2}$, $g_{J_2}=0.890$. The J_1 system is undoubtedly a $(5f)^7\,{}^8S_{7/2}$ state, and the J_2 system is probably a perturbed $(6d)^1\,{}^2D_{3/2}$ state for which, in the absence of mixing, g_J is 0.80. Therefore the ground-state configuration of Cm(I) is very probably $(5f)^7(6d)^1$. Observed intensities and calculated transition probabilities show that all observed J states are within 1500 cm^{-1} of the ground state.

* Work done under the auspices of the U. S. Atomic Energy Commission.

E8. Hyperfine-Structure Investigations of Protactinium-233.* J. C. HUBBS AND J. WINOCUR, *Radiation Laboratory and Department of Physics, University of California, Berkeley.*—The atomic-beam magnetic-resonance method has been used to investigate 27-day Pa^{233} in the Zeeman region of hyperfine structure. The nuclear spin of Pa^{233} is found to be 3/2. Three low-lying electronic energy levels $J=11/2$, $g_J=0.8144\pm0.0015$; $J=9/2$, $g_J=0.8066\pm0.0015$; and $J=7/2$, $g_J=0.7922\pm0.0030$ are found. Transition intensities indicate that the level ordering is probably inverted, and that all observed J states are within 2000 cm^{-1} of the ground state. The observed g_J values are those calculated for two weakly interacting systems $J_1=4$, $g_{J_1}=0.793$ and $J_2=3/2$, $g_{J_2}=0.873$. The J_1 system is evidently a ${}^3H_4$ term from $(5f)^2$ and the J_2 system is probably a perturbed $(6d)^1\,{}^2D_{3/2}$ state for which, in the absence of mixing, g_J is 0.80. Therefore the ground-state configuration of Pa(I) is very probably $(5f)^2(6d)^1$.

* Work done under the auspices of the U. S. Atomic Energy Commission.

E9. The Nuclear Spin of Astatine-211.* E. LIPWORTH, H. L. GARVIN, T. M. GREEN, AND W. A. NIERENBERG, *University of California Radiation Laboratory, Berkeley.*—The nuclear spin of the 7.2-hr astatine-211 (element 85) has been measured by means of an atomic-beam magnetic-resonance experiment. This measurement constitutes the first direct spin determination of an isotope that has no stable counterpart and whose half-life is measured in hours. The At^{211} was produced by an $(\alpha,2n)$ reaction on a bismuth target in the Berkeley 60-in. cyclotron. A bombarding energy of 29 Mev was employed to produce preferentially At^{211} free of At^{210}. The astatine was separated from the bismuth target by evaporation, then mixed with a carrier of natural iodine, its lower homolog. The mixture was introduced into the atomic beam apparatus through a heated platinum tube to dissociate the I-At complex. The active beam was collected on buttons coated with evaporated silver, which were counted in continuous-flow proportional counters. The electronic ground state of astatine is $P_{3/2}$, and the two observable "flop-in" resonances have been observed at three different fields of 2.86, 5.71, and 8.56 gauss. All resonances observed are consistent with an assignment of 9/2 for the nuclear spin of At^{211}.

* Done under the auspices of the U. S. Atomic Energy Commission.

E10. Nuclear Spin of Tl^{202}.* LAWRENCE L. MARINO, W. BRUCE EWBANK, HOWARD A. SHUGART, AND HENRY B. SILSBEE, *University of California, Berkeley.*—The nuclear spin of $I=2$ has been measured for 12 day Tl^{202} by the atomic-beam, magnetic-resonance technique using radioactive detection. The "flop-in" transition of the ${}^2P_{\frac{1}{2}}$, $F=\frac{1}{2}$, $m_F=-\frac{1}{2}\leftrightarrow m_F=-\frac{1}{2}$ states was observed at 2.4 and 4.9 Mc/sec. Identification of the isotope responsible for the signal is based on half-life analysis. The isotope was prepared by $Hg(\alpha,kn)Tl$ reactions with 24-Mev deuterons from the 60-in. Berkeley cyclotron. Separation of the thallium from the mercury target was accomplished by distillation. Thallium atoms passing through the apparatus were collected on sulfur-coated surfaces and detected by counting k x-rays following electron capture. The measured spin is observed to be the same as that of Tl^{200} [1] and Tl^{204} [2].

* This research was supported in part by the U. S. Atomic Energy Commission and the Office of Naval Research.

[1] Marino, Brink, Ewbank, Shugart, and Sielsbee, Bull. Am. Phys. Soc. Ser. II, **3**, 186 (1958).

[2] Brink, Hubbs, Nierenberg, and Worcester, Bull. Am. Phys. Soc. Ser. I, **7**, 343 (1956); Ser. II, **4**, 200 (1957); Phys. Rev. **107**, 189 (1957).

E11. Indirect Proton Spin Coupling and Rotational Barriers in Hydrocarbon Molecules. GILDA MAKI, *University of California Radiation Laboratory, Livermore.*—A calculation of the relative values of $J_{HH'}$ the indirect spin-coupling parameter was made for the singlet systems CH_2 and C_2H_2 to determine the dependence of the coupling on the number of intermediate bonds and the relative orientation of the protons. Ramsey's model of electron-nuclear spin coupling was used and only the contribution to J from the electron spin-nuclear spin contact interaction term in the total Hamiltonian was considered. Ground-state molecular wave functions needed for the calculation of J were obtained as linear combinations of all the singlet states of the systems by the variational method. Linear combinations of Slater atomic orbitals were used for the one electron functions and only nearest neighbor interactions were considered. Variations in the relative orientation of the protons in these systems due eitner to changes in bond angle or rotation about the C-C axis were taken into account by appropriate changes in the hybridization of the one electron functions. This resulted in a change in the ground-state energy and eigenfunction. Hence the energy barrier to internal rotation and dependence of J upon the orientation could be estimated.

TUESDAY AFTERNOON AT 2:00

Physics 201

(A. M. CROOKER presiding)

Spectroscopy

Invited Paper

F1. Problems of Publication and Authority in the Analysis of Spectra. ALLEN G. SHENSTONE, *Palmer Laboratory, Princeton University.* (30 min.)

Contributed Papers

F2. The Hydrogen Molecule—Hydrogen Atom Interaction. HENRY AROESTE AND WILLIAM J. JAMESON, JR., *Lockheed Missile Systems Division Research and Development Laboratory.*—The interaction potential for a hydrogen atom with a hydrogen molecule has been given from experimental[1] and theoretical[2] considerations. For the range in which a comparison may be made the experimental results are considerably lower. A similar situation arises in the He-He interaction, and the interpretation of the experimental work by means of classical mechanics has been criticized.[3] The arguments on both sides, however, appear inconclusive.[4] The results from considerations to revise downward the theoretical values of the hydrogen atom–hydrogen molecule interaction will be presented.

[1] Amdur, Kells, and Davenport, J. Chem. Phys. **18**, 1676 (1950).
[2] H. Margenau, Phys. Rev. **66**, 303 (1944).
[3] T. Wu, J. Chem. Phys. **28**, 986 (1958).
[4] I. Amdur, J. Chem. Phys. **28**, 987 (1958).

F3. Consideration of Radial Correlation in the Calculation of the Binding Energy of He_2^+ Molecular Ion. P. CSAVINSZKY,* *National Research Council of Canada, Ottawa* (introduced by Ta-You Wu).—A variational calculation has been carried out to determine the binding energy of He_2^+ molecular ion at the experimental value of the internuclear separation. The wave function has been constructed according to the valence bond method with effective nuclear charges Z', Z'', Z''' as variational parameters. For infinite internuclear separation the wave function for the He atom is of the Eckart type. Comparison of the binding energy (obtained with a single set of Z', Z'', Z''' values) with the values calculated by other authors without correlation allowance shows that the shell-opening as given by the Eckart-type wave function is effective also in a three-electron system.

* National Research Laboratories Postdoctorate Fellow.

F4. Electronic Structures of Small Diatomic Molecules. FRANK E. HARRIS, *University of California, Berkeley.**—An IBM 701 computer has been programed to compute the Hamiltonian matrix of an arbitrary diatomic molecule, using as bases products of one-electron wave functions. The program constructs wave functions of proper spin and of proper permutational symmetry, and automatically selects, computes, and combines the necessary integrals. At present the one-electron functions are simple expressions in prolate spheroidal coordinates.[1] This program has been applied to LiH, H_2, and HeH^+. The results indicate that the use of a modest number of carefully chosen one-electron functions accounts for electronic interactions to an extent previously thought to be possible only by explicitly introducing inter-electronic distances into the wave functions.

* The computations described here were supported in part by the National Science Foundation. The author has also received support as an Alfred P. Sloan Research Fellow.
[1] Frank E. Harris, J. Chem. Phys. **27**, 812 (1957).

F5. Nitric Oxide Vibrational Relaxation. F. A. ROBBEN, *Lockheed Missile Systems Division* (introduced by D. Bershader).—Measurements of the vibrational relaxation of nitric oxide have been made at temperatures ranging from 450°K to 600°K and densities of about 0.05 atmos. The relaxation time corrected to atmosphere density, τ_0, ranges from about 0.3 μsec to 0.9 μsec, with an uncertainty of about ±0.2 μsec. At 500°K, the probability of de-excitation from the first vibrational level ($P_{1\to0}$)[1] is then 4.3×10^{-4} per collision. Schwartz, Slawsky, and Herzfeld[2] describe a quantum mechanical method of computation of $P_{1\to0}$, and following this, we find $P_{1\to0}=9\times10^{-10}$. A reasonable way to explain the discrepancy is that there are intermolecular forces at short range which are not described by the Lennard-Jones type potential. The measurements were made in a shock tube, the absorption of the first vibrational level ($\gamma_{0\to1}$ band) being used to measure the density of vibrationally excited nitric oxide. The absorption was measured photoelectrically, with a spectrograph to isolate the band in question.

[1] K. F. Herzfeld, *Relaxation Phenomena in Gases, Thermodynamics and Physics of Matter* (Princeton University Press, Princeton, New Jersey, 1953).
[2] R. N. Schwartz and K. F. Herzfeld, J. Chem. Phys. **22**, 767 (1954).

F6. Photoelectric Absorption Coefficients for High Temperature Air.* B. H. ARMSTRONG AND R. E. MEYEROTT, *Lockheed Aircraft Corporation, Missile Systems Division.*—The photoelectric absorption coefficients of pure N and O and of air have been computed over the temperature range 2 to 20 ev, density range $\sim10^{-5}$ normal to normal, and frequency range 1 ev to 1 kev. The occupations of ionic states were computed with the grand canonical ensemble statistical method described by Brachman and Meyerott.[1] For terms of principal quantum numbers 2 and 3, empirical energy values were used where known, and estimates by isoelectronic interpolation or the Bacher-Goudsmit method[2] were made where empirical values are lacking. For $n\geq4$, the Bohr formula with quantum defects was used, separate angular momentum levels being included to $n=9$. Multiple excitations were partially included by using one-electron levels of ionic cores for all core possibilities of the $n=2$ shell. Screened Coulomb gaunt factors were used, and fractional parentage coefficients employed in order to properly account for transitions from equivalent electron states. The large number of 3 angular momentum configurations included necessitated the calculation of about 900 fps. These were calculated using recently devised formulas kindly supplied in advance of publication by Mr. Paul Kelly.

* This work was supported by the Air Force Special Weapons Research Center, Kirtland Air Force Base, New Mexico.
[1] M. K. Brachman and R. E. Meyerott, ANL-4986 (unpublished).
[2] R. F. Bacher and S. Goudsmit, Phys. Rev. **46**, 948 (1934).

F7. Detection of Atoms in the Nitrogen Afterglow.* ROBERT A. YOUNG AND ROBERT SHARPLESS, *University of Washington, Seattle.*—Using a high sensitivity ($\sim10^{-5}$ mm Hg atomic partial pressure), fast response (~1 sec), Wrede gauge we have measured the atom concentration as a function of time for two minutes during the decay of the active nitrogen. The nitrogen afterglow, in a two liter glass bulb coated exteriorly with MgO, is simultaneously observed through a 5790 A interference filter by a photomultiplier (RCA 6655). The light detection and collection system has been calibrated. We find the following: (1) the atoms exhibit a three body recombination early in the afterglow ($k_n=2.8\ 10^{16}$ cc²/mole² sec, $p=0.89$ mm Hg, $(N)\sim2\ 10^{-4}$ mm Hg partial pressure) and exponential decay during the later stages of the afterflow ($\tau=30$ sec, $p=0.89$ mm Hg, $(N)\sim2\ 10^{-5}$ mm Hg, accommodation coefficient $\sim10^{-3}$); (2) the nitrogen first positive band radiation also decays exponentially but with a decay constant unrelated to that of the atoms; (3) the rate constant k_1 for the production of the nitrogen first positive band emission is $k_1=1.6\ 10^{14}$ cc²/mole² sec derived from the early three body decay. Using this value for k_1, the observed atomic concentration during the exponential decay would produce less emission than observed.

* Supported by the Air Force Research and Development Command.

F8. Negative Lithium Ions. SAMUEL K. ALLISON, *University of Chicago.*—Experiments have been made on the relative yield of Li^- ions produced after charge equilibration of a Li^+ beam in traversing a gas cell. In addition to intrinsic scientific interest the studies might lead to the design of a Li^- ion

source for a tandem van de Graaff generator. Li^+ beams at kinetic energies from 15 to 50 kev were passed through a gas cell 10 cm long containing various gases at pressures from 1 to 10 μ. The emergent lithium beam was magnetically analyzed for its charge constituents. Converter gases tried have been H_2, N_2, N_2O, NO, C_3H_8 (propane). In the three heavier gases Li^-/Li^+ ratios of $\sim 4\times10^{-4}$ were observed at 50 kev, with indications that the maximum relative yield occurs at higher kinetic energies. H_2 and N_2 were less efficient as converter gases by factors of 5 and 2, respectively. Secondary electron emission induced in a Be-Cu detector was used as a measure of beam intensity and no correction to the above Li^-/Li^+ estimate has as yet been made due to different efficiencies of Li^- and Li^+ in producing electrons. The charge changing cross-section sums $(\sigma_{1^0}+\sigma_{1^1})$, $(\sigma_{0^1}+\sigma_{0^1})$, and $(\sigma_{1^1}+\sigma_{1^0})$ have been measured. At 40 kev, in H_2 gas, they are 70, 12, and 2.9×10^{-17} cm^2, respectively, per hydrogen atom traversed.

F9. Free-Free Absorption Coefficient in a Fully Ionized Gas. HUGH E. DEWITT, *University of California Radiation Laboratory, Livermore.*—The calculation of the bremsstrahlung rate and the inverse process of absorption by free-free electron transitions in fully ionized gases requires the use of the screened Coulomb potential felt by an electron in the neighborhood of an ion.[1] The bremsstrahlung and free-free absorption cross sections have been calculated for the Debye form of the screened Coulomb potential classically and quantum mechanically in Born approximation. The free-free absorption coefficient was obtained by averaging over the Maxwell velocity distribution of the electrons. The effect of screening was found to depend on a parameter $b=\hbar/2m\omega\lambda^2$ where ω is the frequency of absorbed radiation and λ is the Debye screening length. Over the higher frequency part of the spectrum where $b<1$, our result is smaller than the absorption coefficient for the pure Coulomb field[2] by a term of order b. In the microwave part of the spectrum, $b>1$, the absorption coefficient is of order $1/b^2$, and for some temperatures and densities is very much less than the results of Burkhardt, Elwert, and Unsöld[3] who neglected screening.

[1] H. E. DeWitt and R. E. Kidder, Phys. Rev. (to be published).
[2] W. J. Karzas and Richard Latter, Rand Corporation Research Memorandum RM-2010-AEC.
[3] Burkhardt, Elwert, and Unsöld, Z. Astrophysik **25**, 310 (1949).

F10. Spark Spectra of Arsenic. R. E. BEDFORD AND A. M. CROOKER, *The University of British Columbia.*—The spectra of arsenic have been rephotographed in the region λλ 527–9300 A, principally on a 21-ft concave grating and the resulting lines classified. The principal extensions are in As II, where the analysis of A. S. Rao[1] has been extended by the addition of even terms from $4p6p$ and $4p4f$ and the odd terms of $4p5d$, $4p6s$, $4p7s$, $4p8s$. The analysis is supported by the hfs on our plates as well as independently by Tolansky, Rao, and Murakawa. The Zeeman effect data of Green and Barrows[2] has also been very useful in confirming the analysis.

[1] A. S. Rao, Ind. J. Phys. **7**, 561 (1932).
[2] J. B. Green and W. M. Barrows, Phys. Rev. **47**, 135 (1935).

F11. Spectrum of Zinc III. A. M. CROOKER AND F. GUTMANN, *The University of British Columbia.*—The spectra of zinc have been photographed in the region λλ 2025–8000 A, principally on a 21-ft concave grating. This has permitted an extension of the NiI isoelectronic sequence. Although the analysis is far from complete, we have already found new terms which undoubtedly arise from the configurations $3d^94f$, $3d^95p$, and $3d^96s$. The hydrogenic terms $3d^94f$ and the series members of $3d^95p$ confirm the series limit suggested by Catalan.[1] The $3d^94f$ and $3d^95g$ terms should be good tests of (jl) coupling theory.[2]

[1] C. E. Moore, Natl. Bur. Standards Circ. No. 467 (1952), p. 128.
[2] G. H. Shortley and B. Fried, Phys. Rev. **54**, 749 (1938).

WEDNESDAY MORNING AT 9:30

Physics 200

(S. H. NEDDERMEYER presiding)

Invited Papers on High-Energy Physics

G1. Energy Dependence of Antiproton Cross Sections in Hydrogen. BRUCE CORK, *University of California Radiation Laboratory, Berkeley.* (30 min.)
G2. Hyperon-Nucleon Interactions. RICHARD H. DALITZ, *Enrico Fermi Institute, Chicago.* (30 min.)
G3. Photoproduction of Strange Particles. BOYCE D. MCDANIEL, *Cornell University.* (30 min.)
G4. Pi Meson Photoproduction. WILLIAM M. WOODWARD, *Cornell University.* (30 min.)
G5. Hyperon and Heavy Meson Interactions. JACK STEINBERGER, *Columbia University.* (30 min.)

WEDNESDAY MORNING AT 9:30

Physics 201

(B. A. JACOBSOHN presiding)

Low-Energy Nuclear Physics II

H1. High-Current 400-kv Cockcroft-Walton Accelerator for Nuclear Research.* R. W. FINK, *University of Arkansas.*—Operating characteristics of the Arkansas accelerator will be discussed. This facility provides continuous beams of hydrogen isotope ions up to 2 ma and is housed in a deep underground building designed for adequate neutron shielding. Measurements are underway of cross sections for *DD* and *DT* neutrons, e.g., (n,p), (n,α), (n,n), (n,np), (n,t), (n,γ), and $(n,$ fission) both by radiochemical and nuclear emulsion techniques, for comparison with existing nuclear reaction theory. Some new cross-section results on Bi, Ti, Mg, Al, and B will be summarized. The energy and angular distributions of emitted charged

particles, especially across closed shells, are being studied. A corollary of this is a study of unknown radioactive species produced from enriched stable isotopes by fast neutron bombardment. Optical spectroscopy studies are underway on atomic-molecular reactions which occur when ion beams of well-defined energy and compositon impinge on various gases, e.g., N_2, O_2, A, H_2; such reactions are of interest in interpreting auroral phenomena. Continuous neutron yields so far achieved are 4×10^{10} *DT* neutrons/sec (ZrT targets) and 7×10^{8} *DD* neutrons/sec (zirconium deuteride target). Target techniques and limitations will be discussed along with results obtained to date.

* Supported in part by the U. S. Atomic Energy Commission.

H2. New Isotopes of Cobalt; (n,p) and (n,np) Reactions of Nickel with 14.8-Mev Neutrons.* I. L. PREISS AND R. W. FINK, *University of Arkansas.*—Three new cobalt activities have been observed from bombardments of enriched Ni^{64} with 14.8-Mev neutrons at fluxes of $(1–4)\times10^{8}$ neutrons/cm² sec. The neutron flux was monitored with thin copper foils using the $Cu^{63}(n,2n)Cu^{62}$ (9.9 min) cross section reported by Yasumi.[1] Mass assignments were made by means of cross-bombardments of enriched Ni^{62} and Ni^{64} samples, containing about 2% Ni^{58} as an isotopic impurity, at neutron energies of 2.95 Mev and 14.8 Mev. The observed mass assignments, half-lives, and cross sections at 14.8 Mev are as follows: $Ni^{64}(n,p)Co^{64m}$ (upper state), 2.0 ± 0.2 min, 0.43 ± 0.02 mb; $Ni^{64}(n,p)Co^{64g}$ (lower state), 7.8 ± 0.2 min, 4.10 ± 0.05 mb; $Ni^{64}(n,np)Co^{63}$, 1.40 ± 0.05 hr, 0.93 ± 0.04 mb; $Ni^{62}(n,p)Co^{62m}$ (upper state), 1.9 ± 0.3 min, 0.20 ± 0.05 mb; $Ni^{62}(n,p)Co^{62g}$ (lower state), 13.8 ± 0.2 min, 3.3 ± 0.2 mb; $Ni^{58}(n,p)Co^{58m}$ (upper state), 9.1 ± 0.3 hr, 125 ± 30 mb. The decay schemes of the new activities appear to be quite complex, each exhibiting hard beta particles and several gamma rays.

* Supported in part by the U. S. Atomic Energy Commission.
[1] S. Yasumi, J. Phys. Soc. (Japan) 12, 443 (1957).

H3. $C^{14}(p,p)C^{14}$ and $C^{14}(p,\gamma)N^{15}$ Reactions.* D. F. HEBBARD, *Kellogg Radiation Laboratory, California Institute of Technology,* AND D. N. F. DUNBAR, *University of Melbourne, Australia.*—The elastic scattering of protons from C^{14} has been investigated for the range of proton energies from 340 to 690 kev. The elastic scattering data at the 530-kev resonance, combined with the gamma-ray angular distribution,[1] is consistent only with a spin and parity assignment $\frac{3}{2}+$. The proton width of this resonance is estimated to be 200 ev. No elastic scattering anomalies were observable at the 351-kev or the 635-kev resonances, nor any anomaly near the neutron threshold at 671.5 kev. The nature of the radiation from the 351-kev resonance has been determined, and radiative widths are estimated. The 261-kev resonance in the $C^{14}(p,\gamma)$ reaction has been detected for the first time, and an estimate of the proton and radiative widths has been made. The radiative widths of the 530-kev and 635-kev resonances have been remeasured, leading to an appreciably larger width at 635 kev. The bearing of these results on the problem of the capture of thermal neutrons by N^{14} will be discussed.

* Assisted in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and the program of the University of Melbourne.
[1] Bartholomew, Brown, Gove, Litherland, and Paul, Can. J. Phys. 33, 441 (1955).

H4. The $D(p,\gamma)He^3$ Reaction at Low Energies. G. M. GRIFFITHS, E. A. LARSON, AND L. P. ROBERTSON, *University of British Columbia* (introduced by Dr. J. B. Warren).—The $D(p,\gamma)He^3$ reaction has been studied in the energy range 300 kev to 1.8 Mev using ice targets of measured thickness and a scintillation counter whose efficiency was previously determined by simultaneous counting of α particles and γ rays from the $F^{19}(p,\gamma,\alpha)O^{16}$ reaction at the 340-kev resonance. The measured cross section at 1.0-Mev bombarding energy was $(3.2\pm0.3)\times10^{-30}$ cm². The results show that the cross section is represented better, with respect to magnitude and energy dependence, by the theoretical results of Gunn and Irving[1] based on exponential type wave functions than by results based on Gaussian functions.[1,2] The ratio of the magnetic dipole radiation cross section to the electric dipole radiation cross section as a function of energy was obtained from detailed angular distribution measurements and is in reasonable agreement with the theoretical results of M. Verde[2] thus providing a rough estimate of the *D*-state probability in the He^3 ground state.

[1] J. C. Gunn, Phil. Mag. 42, 1353 (1951).
[2] M. Verde, Helv. Phys. Acta 23, 453 (1950).

H5. Cross Section for the $Li^7(n,\gamma)Li^8$ Reaction. W. L. IMHOF, R. G. JOHNSON, F. J. VAUGHN, AND M. WALT, *Lockheed Missile Systems Division.*—Cross sections for the $Li^7(n,\gamma)Li^8$ reaction have been measured between 150 kev and 1000 kev with an energy resolution of about 60 kev. The neutrons were produced by bombarding a lithium target with the proton beam from a Van de Graaff accelerator. The reaction was detected by observing the decay of Li^8 nuclei produced in a 1-in. diameter by 1-in. long LiI crystal. The pulses from the crystal were analyzed between beam bursts of 3-sec duration with a slow time-to-pulse-height converter and a 100-channel pulse-height analyzer. The observed 0.88 ± 0.04 sec half-life provided a convenient identification of the Li^8 decays. To prevent counting the iodine activity induced in the scintillator, energy discrimination was used. For obtaining absolute cross-section values the pulse-height distribution in the crystal of the 13-Mev Li^8 beta spectrum was measured. This spectrum will be presented along with the cross section data.

H6. Capture Cross Sections for Moderate Energy Charged Particles.* J. B. BALL, A. W. FAIRHALL, AND I. HALPERN, *University of Washington.*—Excitation functions of several deuteron and alpha radiative capture reactions have been studied in the region of excitation energies from 10 to 30 Mev using radiochemical techniques. Excitation functions will be presented for the reactions $N^{14}(\alpha,\gamma)F^{18}$, $A^{40}(d,\gamma)K^{42}$, $Ni^{58}(\alpha,\gamma)Zn^{62}$, $Xe^{136}(\alpha,\gamma)Ba^{140}$, and $Ba^{138}(d,\gamma)La^{140}$. All of the excitation functions rise to maxima in the region of 21 ± 1 Mev and fall rapidly above this energy. The cross sections at the maxima are, respectively: 2.1 ± 0.3 mb, 75 ± 15 μb, 400 ± 25 μb, 55 ± 5 μb, and 65 ± 10 μb. The reaction $He^3(\alpha,\gamma)Be^7$ has been studied up to an excitation energy of 18 Mev. At this energy the cross section has risen to a value of 110 ± 35 mb. Except for helium and nitrogen, the low-energy portions of the excitation functions are severely affected by the particle barrier penetration factors. The types of curves obtained by dividing the excitation functions by the appropriate formation cross sections will be discussed.

* Supported in part by the U. S. Atomic Energy Commission.

H7. Model for the Medium Energy (α,γ) Reaction.* V. A. MADSEN AND E. M. HENLEY, *University of Washington.*—An attempt has been made to explain capture cross section measurements[1,2] performed with α particles of 10–38 Mev. The compound nucleus model and detailed balance were used[3] together with the following assumptions: no more than two γ rays are emitted in the decay to any state below the relevant particle separation energy; the γ-capture cross section from an excited state has the same giant resonance behavior as from the ground state; the nuclear level density at excitation energy E^* is $W(E^*)=C\exp\{(aE^*)^{\frac{1}{2}}\}$. The magnitude and energy dependence of the cross section for the reaction $Xe^{136}(\alpha,\gamma)Ba^{140}$ can be reproduced if a is chosen to be rather small (2.5 Mev^{-1}). The data for the reaction $Ni^{58}(\alpha,\gamma)Zn^{62}$

can be explained semiquantitatively with $a=2$, which is about that used at lower excitation energies. The approximations of the model and its application to the (p,γ)[3] and (d,γ)[1] reactions will be discussed.

* Supported in part by the U. S. Atomic Energy Commission.
[1] Ball, Fairhall, and Halpern, Cyclotron Research, University of Washington, Annual Progress Reports, 1957 and 1958 (unpublished).
[2] H. Morinaga, Phys. Rev. 101, 100 (1956).
[3] E. L. Kelly, UCRL Report 1044 (unpublished).

H8. $C^{12}(He^3,\alpha)C^{11}$, $C^{12}(He^3, d,$ and $np)N^{13}$, and $Al^{27}(He^3,2\alpha)Na^{22}$ Excitation Functions from 13 to 21 Mev.* D. R. F. COCHRAN AND J. D. KNIGHT, *Los Alamos Scientific Laboratory.*—Partial excitation functions for production of C^{11} and N^{13} from carbon and Na^{22} from aluminum have been measured by stacked-foil experiments with 20.81 ± 0.11 Mev incident He^3 ions. The carbon reactions were carried out with stacks of polyethylene foils interspaced with aluminum catcher foils. The aluminum reactions were studied in separate runs. The carbon results are given in Table I. Bombardment

TABLE I.

Nominal energy range (Mev)	Cross section (mb)±10% C^{11}	N^{13}
20.3–19.6	111	82
19.6–18.9	118	86
19.1–18.3	114	86
18.4–17.6	115	85
17.9–17.1	144	994
17.2–16.3	155	96
16.6–15.7	141	90
15.8–14.9	157	104
15.2–14.3	158	111
14.4–13.4	174	109

of a thick graphite target gave 1.3×10^{-4} atoms of Be^7 per incident He^3. The $Al^{27}(He^3,2\alpha)Na^{22}$ cross section varies approximately linearly from 7 mb at 11.0 Mev to a peak of 32 mb at 19.5 Mev.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

H9. Angular Distribution of $D(d,n)He^3$ Neutrons.* M. D. GOLDBERG AND J. M. LEBLANC, *University of California Radiation Laboratory, Livermore.*—The angular distribution of neutrons produced in $D(d,n)He^3$ reaction has been measured from 0–60° in the laboratory system, using 5.0-, 7.6-, and 12.2-Mev deuterons from the Livermore variable-energy cyclotron. The neutrons were detected by means of a proton-recoil telescope, mounted on an angle changer, which contains two proportional counters and a CsI scintillator. Pulses in the scintillator that were in coincidence with pulses in the two proportional counters were pulse-height analyzed to select neutrons from the *D-d* reaction. The incident flux was monitored by integrating the current received by the gas target and also by means of another proton-recoil telescope which remained fixed during the experiment. The distributions at all energies are very peaked in the forward direction, with a first minimum around 30–40° and a subsequent smaller maximum. The angular resolution width was about 2°. The shapes of the distributions are in good agreement, in the region of overlap, with previous data.[1]

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] Brolley, Putnam, and Rosen, Phys. Rev. 107, 820 (1957).

H10. Breakup of the Be^9 2.43-Mev Level.* P. D. KUNZ AND E. M. HENLEY, *University of Washington.*—The decay of the 2.43-Mev excited state of Be^9 can energetically proceed through the following modes: (1) $Be^{9*}\rightarrow Be^5+n$, $Be^5\rightarrow He^4+He^4$, (2) $Be^{9*}\rightarrow He^5+He^4$, $He^5\rightarrow He^4+n$, (3) $Be^{9*}\rightarrow He^4+He^4+n$, (4) $Be^{9*}\rightarrow Be^9+\gamma$. From the commonly accepted spin and parity assignments of $\frac{1}{2}^-$, one can show from just angular momentum and parity arguments that strict application of the usual alpha-particle model with a central neutron potential, or shell model neglecting center-of-mass effects, predicts no decay through mode (1), while modes (2), (3), and (4) are allowed. A variational calculation based on the alpha-particle model was made using a nonspherical neutron potential to mix in higher angular momentum states by which decay through mode (1) can proceed, although mode (2) is still dominant. The ratios of the decay rates through the different modes, together with the energy and angular distributions of the emitted alpha particles will be compared with experiment.[1]

* Supported in part by the U. S. Atomic Energy Commission.
[1] Bodansky, Eccles, and Halpern, Phys. Rev. 108, 1019 (1957).

H11. Coincidence Studies of the Reactions $Li^6(d,n\gamma)Be^7$, $Be^9(d,n\gamma)B^{10}$, and $B^{11}(d,n\gamma)C^{12}$. I. Experimental. G. C. NEILSON, W. K. DAWSON, AND J. T. SAMPLE, *Defence Research Board.*—An improved fast neutron time-of-flight spectrometer[1] will be described in which the initial signal for the time measurement is derived from coincident gamma rays. Results for the reaction $Li^6(d,n\gamma)Be^7$, $Be^9(d,n\gamma)B^{10}$, and $B^{11}(d,n\gamma)C^{12}$ will be presented. Neutron groups to the following excited states have been observed; Be^{7*} 0.4[2] Mev; B^{10*} 0.72, 1.74, 2.15, 3.58, and 5.16 Mev; C^{12*} 4.43 Mev. The total cross sections for the neutron groups corresponding to the first four excited states of B^{10} are smoothly rising functions of deuteron energy (0.75→2.0 Mev). The angular correlations for $Li^6(d,n\gamma)Be^7$ are independent of the gamma-ray counter position but depend strongly on the position of the neutron counter with respect to the deuteron beam. The angular distribution of the neutrons with respect to the beam direction shows the characteristic stripping peak ($lp=1$) at $E_D=1.00$ Mev. This peak becomes more pronounced at higher energies (1.5, 2.0, 2.3 Mev).

[1] G. C. Neilson and D. B. James, Rev. Sci. Instr. 26, 103, 1018 (1955).

H12. Coincidence Studies of the Reactions $Li^6(d,n\gamma)Be^7$, $Be^9(d,n\gamma)B^{10}$, and $B^{11}(d,n\gamma)C^{12}$. II. Results. W. K. DAWSON, G. C. NEILSON, AND J. T. SAMPLE, *Defence Research Board.*—Angular correlations of neutrons in coincidence with gamma rays were measured for the reactions $Be^9(d,n\gamma)B^{10}$ and $B^{11}(d,n\gamma)C^{12}$ using the apparatus described in the previous abstract. Incident deuteron energies ranged from 0.50 to 2.00 Mev. The differential cross section for the emission of neutrons as a function of angle was found to be independent of the angular position of the gamma counter for the $Be^9(d,n\gamma)B^{10}$ reaction. Hence neutron angular distributions were obtained by keeping the gamma counter at a fixed angle and swinging the neutron counter about the target. Such distributions will be presented for $B^{10*}=0.72$, 1.74, 2.15, 3.58 Mev for $E_D=0.95$, 1.50, and 2.00 Mev and for $B^{10*}=5.16$ Mev at $E_D=2.00$ Mev. By direct measurement the mean life of the 0.72-Mev B^{10} state was found to be $(0.96\pm0.10)\times10^{-9}$ sec. Only neutrons leading to the 4.43-Mev state of C^{12} were observed from the $B^{11}(d,n\gamma)C^{12}$ reaction. Angular correlations at various deuteron energies for this reaction will be presented.

H13. Coincidence Studies of the Reactions $Li^6(d,n\gamma)Be^7$, $Be^9(d,n\gamma)B^{10}$, and $B^{11}(d,n\gamma)C^{12}$. III. Interpretation. J. T. SAMPLE, W. K. DAWSON, AND G. C. NEILSON, *Defence Research Broad.*—The neutron angular distributions for the $Li^6(d,n\gamma)Be^7$ reaction (430-kev level) are well fitted by Butler's[1] theory with $R=5.2\times10^{-13}$ cm and $lp=1$. Together with the isotropic $n-\gamma$ angular correlation, this indicates that the 430-kev state of Be^7 has $J=\frac{1}{2}^-$. The angular distributions of the neutron groups from $Be^9(d,n\gamma)B^{10}$ are not well fitted by Butler's theory for reasonable values of the radius parameter, though stripping is evident at higher bombarding energies. The assumption of heavy particle stripping interfer-

ing with deuteron stripping[2] provides approximate agreement with some of the data. The group leaving B^{10} in the 3.58-Mev state shows anomalous behavior, the angular distribution at lower bombarding energies appearing to be due to deuteron stripping with $lp=1$, but deviating widely from this at higher bombarding energies. The isotropic $\pi-\gamma$ correlations are consistent with Satchler's[3] theory, assuming that the excited states of B^{10} are formed by direct interaction.

[1] S. T. Butler, Proc. Roy. Soc. (London) **A203**, 559 (1951).
[2] G. E. Owen and L. Madansky, Phys. Rev. **105**, 1766 (1957).
[3] S. R. Satchler, Proc. Phys. Soc. (London) **A66**, 1081 (1953).

WEDNESDAY MORNING AT 9:30

Physics 202

(E. L. HAHN presiding)

Resonance Physics II

I1. Nuclear Audio-Frequency Spin Absorption in Metals. A. G. ANDERSON, *IBM Watson Laboratory*.—Nuclear audio-frequency spin absorption has been observed in the metals lithium, sodium, and aluminum by means of the technique of Ramsey and Pound.[1] In lithium and sodium the observed second moment of the absorption line at zero applied dc magnetic field is in agreement with calculations based on the dipole-dipole interaction; in aluminum the zero field absorption extends to frequencies as high as 50 kc and the second moment of the absorption line appears to be about 50% larger than expected from theory. Nuclear spin absorption has also been observed at small applied dc magnetic fields, H_0, for audio-frequency magnetic excitation both parallel to and perpendicular to H_0; in both of these cases, absorption is observed at γH_0 and $2\gamma H_0$ in agreement with the theory of Broer.[2]

[1] N. F. Ramsey and R. V. Pound, Phys. Rev. **81**, 278 (1951).
[2] L. J. F. Broer, Physica **10**, 801 (1943).

I2. Nuclear Spin Relaxation in Liquid Methane. H. S. SANDHU AND M. BLOOM, *University of British Columbia*.—The spin-lattice relaxation time T_1 has been measured for protons in liquid methane from 91 to 110°K and in the solid just below the melting point using pulse techniques. A very small amount of oxygen has been found to shorten T_1 appreciably and our purest samples give T_1 of about 2 sec at 110°K, more than 100 times longer than previously reported values.[1] T_1 is found to decrease with decreasing temperature and is slightly less than one second in the solid near the melting point. We shall report quantitative measurements of T_1 *versus* temperature as a function of oxygen and nitrogen concentrations, the impurity concentrations being measured with mass spectrometer. These measurements are part of a program to measure nuclear spin relaxation times in CH_4, CH_3D, CH_2D_2, CHD_3, and CD_4 from the boiling point down to liquid helium temperatures. In addition to obtaining information on the liquid and solid-state properties of the systems being investigated, the aim is to gain insight into the influence of molecular symmetry on nuclear spin relaxation.

[1] Thomas, Alper, and Torrey, J. Chem. Phys. **18**, 1511 (1950).

I3. Study of Hyperfine Structure of $(SO_3)_2NO^{--}$ by Means of Nuclear Magnetic Resonance. J. M. ROCARD, *University of Geneva* (introduced by G. J. Béné).—A crossed-coil spectrometer operating at 8.4 kcps with a phase sensitive detector at the Larmor frequency was used to study the splittings due to indirect coupling in molecules containing the nuclei ^{14}N and ^1H in samples of 2000 cc.[1] By reducing the volume of the sample to 50 cc and by using the enhancement of nuclear polarization due to the Overhauser effect,[2] the same spectrometer was used to study the hyperfine structure of $(SO_3)_2NO^{--}$. The amplitude of the nuclear signal was observed and it was made maximum by saturating the π transitions and the σ transitions of the free radical. These experiments gave results in agreement with the Breit-Rabi formula. The results are in Mcps: $\nu_{\pi 1}=52.8$, $\nu_{\sigma 1}=54.4$, $\nu_{\pi 2}=55.8$, $\nu_{\sigma 2}=57.2$, and $\nu_{\pi 3}=58.8$. The enhancement factor of nuclear polarization by saturating the π_2 transitions was about 80, under our experimental conditions.[3]

[1] J. M. Rocard and P. J. Frank, Compt. rend. **246**, 2466 (1958).
[2] Abragam, Combrisson, and Solomon, Compt. rend. **245**, 157 (1957).
[3] Rocard, Roux, Erbéia, and Béné, Arch. sci. Genève (to be published).

I4. Transient Nuclear Quadrupole Resonance Using Circularly Polarized rf.* M. J. WEBER AND E. L. HAHN, *University of California, Berkeley*.—In usual pure quadrupole resonance experiments using linearly polarized rf magnetic fields, both circularly polarized components of the rf field[1] are effective in causing transitions. One sense of rotation excites spins in $+m$ states, while the other excites spins in $-m$ states. A pulsed nuclear induction experiment is performed in which a circularly polarized rf field is applied to excite only one-half of the quadrupolar spin system corresponding to m states of one sign only. The same selective excitation of spins is also obtained by applying two consecutive, equal, linearly polarized rf pulse fields at right angles from the same coherent source, but with the second pulse shifted in phase by 90°. Measurements are made of the Cl^{35} quadrupole resonance in $KClO_3$ at 28 mc. The recovery of the individual $+$ and $-m$-state systems toward thermal equilibrium involves a combination of (1) thermal spin-lattice relaxation processes, and (2) dipole-dipole spin coupling between spins of both m states. Techniques by which (1) and (2) can be separated, and, in addition, how one can determine the individual $\Delta m=\pm 1$ and $\Delta m=\pm 2$ transition probabilities due to quadrupole spin-lattice relaxation are discussed.

* Supported in part by the Office of Naval Research and the U. S. National Security Agency.
[1] Bloom, Hahn, and Herzog, Phys. Rev. **97**, 1699 (1955).

I5. Experiments on Spin-Phonon Interaction in Ruby. K. DRANSFELD, *Bell Telephone Laboratories, Inc.*—The heat conductivity of ruby with 1% Cr_2O_3 was measured at 1.4°K in magnetic fields at right angles to the heat flow. The conductivity was found to agree with that of sapphire. No change in conductivity could be detected when a magnetic field of 5000 gauss was applied, although a change of only 1% would have been apparent. This indicates that those low frequency phonons which lose their momentum by collisions with the spins constitute less than 1% of all phonons. The attenuation of spin temperature was studied at 4°K in a ruby rod, extending between two cavities, 4 mm apart. One end was pumped by 9 kmc-microwave power to a spin temperature of >30°K. No detectable change (<0.1°K) occurred in the temperature of the spins in the second cavity. This result

suggests that the relaxation will be independent of sample size and points to the importance of Raman processes or strong sound absorption at microwave frequencies.

I6. Microwave Zeeman Spectrum of Atomic Fluorine.* H. E. RADFORD, *Yale University.*—A paramagnetic resonance absorption spectrum has been observed at 9100 Mc/sec in the products of a radio-frequency electrodeless discharge in fluorine gas. The spectrum consists of six lines, of roughly equal intensity, widely spaced over a magnetic field interval of 4000–6000 gauss. Absorption widths can be reduced to less than 0.04 gauss at a sufficiently low total pressure in the microwave cavity. A preliminary analysis identifies the lines as arising from $\Delta M=\pm 1$ transitions among the magnetic sublevels of the $^2P_{\frac{1}{2}}$ ground state of atomic fluorine. Because of the intermediate field character of the spectrum, detailed analysis can yield accurate values of both the magnetic moment and the hyperfine structure separation of the fluorine $^2P_{\frac{1}{2}}$ atomic state. Preliminary results are $-g_J(F;{}^2P_{\frac{1}{2}})/g_P=438.5\pm 0.1$ and $\Delta\nu(F;{}^2P_{\frac{1}{2}})=4019\pm 10$ Mc/sec where g_P refers to protons in mineral oil. The effects of minor perturbations of the $^2P_{\frac{1}{2}}$ energy levels are now being calculated, and these calculations together with further measurements should allow more precise values of g_J/g_P and $\Delta\nu$ to be quoted in the near future.

* This work was supported in part by the Office of Naval Research.

I7. Electron Spin Resonance In Electron Irradiated Lithium Sulfate Monohydrate.* P. E. WIGEN AND J. A. COWEN, *Michigan State University.*—Electron spin resonance has been observed in single crystals of lithium sulfate monohydrate irradiated at liquid air temperatures with 1 Mev electrons. One isotropic and four anisotropic lines are observed with a maximum over-all splitting of approximately 60 oe. The anisotropic lines are due to two nonequivalent sites in the lattice. There are two sets of nuclear hyperfine splittings from two nonequivalent nuclei. The anisotropy of the lines and the hfs interactions seem to indicate the paramagnetic entity encompasses a water oxygen and a sulfate oxygen which are hydrogen bonded together. The isotropic line occurs at the free electron g value and is presumably due to another center, perhaps an electron trapped interstitially.

* Supported by the National Science Foundation and by a Michigan State All-University Research Grant.

I8. Influence of Paramagnetic Resonance Saturation on the Faraday Effect. H. WESEMEYER AND J. M. DANIELS, *University of British Columbia* (introduced by M. Bloom).—The paramagnetic Faraday effect, that is the rotation of the plane of polarization of light passing through a paramagnetic salt in a magnetic field, is proportional to the magnetic moment of the salt. When the crystal is exposed to microwave radiation of the frequency which causes paramagnetic resonance, and the microwave power is sufficient to cause appreciable saturation of this resonance, the magnetic moment is reduced and the Faraday rotation should also be reduced as predicted by Kastler (1951). As reported before,[1] we have observed this reduction of the rotation angle in a single crystal of neodymium-ethyl-sulfate at 1.4°K. Linearly polarized light ($\lambda=5461$ A) was propagated along the optic axis of the crystal which was simultaneously exposed to microwave radiation that causes paramagnetic resonance absorption ($S'=\frac{1}{2}$, $g_{11}=3.6$, $\nu=9060$ Mc/sec, $H=1.8$ k oe). From the relative change of the Faraday rotation the spin-lattice relaxation time could be estimated to be 1/20 sec.

[1] H. Wesemeyer and J. M. Daniels, Can. J. Phys. **36**, 405 (1958).

I9. Paramagnetic Relaxation Studies in $(Zn,Ni)SiF_6\cdot 6H_2O$. K. D. BOWERS AND W. B. MIMS, *Bell Telephone Laboratories, Inc.*—Pulsed microwave measurements at helium temperatures and ~4 kmc were made on crystals with differing dilution in zero field. The fractional rate of decay after the end of a "heating" pulse is insensitive ($\leq 10\%$ variation) to whether the crystal is surrounded by gas or liquid, and to whether the microwave frequency corresponds to the center or wing of the absorption line; it increases rapidly as the dilution is decreased and/or the lattice temperature is raised. For very dilute crystals (Zn/Ni~250) the temperature dependence of the decay rate is $T^{3.4}$ between 2.5 and 9°K; below 2.5°K the temperature dependence is less acute. For all dilutions, the decay is not exponential, the fractional rate decreasing markedly with time.

I10. Free Spin Precision in Optically Pumped Alkali Vapor. W. E. BELL AND A. L. BLOOM, *Varian Associates.*—Free precession in magnetic fields ≤ 0.5 gauss has been observed in Na and Rb vapor, signals having been obtained from both Rb^{85} and Rb^{87}. In this experiment a single circularly polarized light beam is passed through the vapor perpendicular to the earth's field, and a polarizing magnetic field slightly stronger than the ambient field provides an axial component parallel to the light beam and allows optical pumping to take place. When the polarizing field is rapidly quenched the pumped spins precess in the ambient field and modulate the transmitted light at the Larmor frequency. In a field of 0.5 gauss, line structure effects are observed which can be attributed to the incipient Back-Goudsmit effect. However, the observed maximum signal lifetimes of about 3 msec appear to be limited at present by residual field inhomogeneity. The method has been used in the earth's field and in fields as weak as 10^{-3} gauss with undiminished signal-to-noise ratio, the lower limit at present being determined by amplifier band passes.

I11. Nuclear Spin-Lattice Relaxation Times T_1 in Alkali Halide Crystals.* E. G. WIKNER AND E. L. HAHN, *University of California, Berkeley.*—Using standard pulse techniques,[1] nuclear spin-lattice relaxation times at room temperature have been measured in a number of alkali halide single crystals. The results obtained are: (1) for Na^{23} in NaCl, NaBr, NaI, respectively, 12, 6.0, and 3.9 sec; (2) for Br^{79} in NaBr, KBr, CsBr, respectively, 0.055, 0.074, and 0.088 sec; (3) for Br^{81} in NaBr, KBr, CsBr, respectively, 0.079, 0.106, and 0.118 sec; and (4) for I^{127} in NaI, KI, CsI, respectively, 0.012, 0.018, and 0.0095 sec. A temperature dependence was also done for Na^{23} in NaCl, $Br^{79,81}$ in KBr, and I^{127} in KI. It was found that the relaxation times followed a T^2 law, as predicted in the theories of Yosida and Moriya[2] and Van Kranendonk,[3] both of whom used a Debye spectrum for the lattice vibration. An attempt will also be made to compare the experimental values with the theoretical values as predicted by Van Kranendonk. Anomalous effects which modify a simple interpretation of experimental results will be pointed out.

* Supported in part by the Office of Naval Research and the U. S. National Security Agency.
[1] E. L. Hahn, Phys. Rev. **80**, 580 (1950).
[2] K. Yosida and T. Moriya, J. Phys. Soc. (Japan) **11**, 33 (1956).
[3] J. Van Kranendonk, Physica **20**, 781 (1954).

I12. Effect of Environment on the Properties of the Cl_2^- Molecule Ion.* W. HAYES, C. J. DELBECQ, AND P. H. YUSTER, *Argonne National Laboratory.*—Recent work[1] showed that the rate of production of Cl_2^- centers in KCl is greatly increased by the addition of silver, lead, thallium, or nitrite ions to the crystal. Efforts were made to determine whether or not the inpurity ions affected the properties of the Cl_2^- center. The properties which were studied are (a) the width and the peak position of the optical absorption band in the ultraviolet, (b) the reorientation temperature after a preferential orientation of the centers has been achieved using polarized light,[1] (c) the

thermal stability of the centers, (d) the parameters of the spin Hamiltonian which describes the resonance spectrum, and (e) the paramagnetic resonance line width. Varying the impurity ion did not lead to an observable variation in any of these properties. The properties of the Cl_2^- center have since been studied in the series LiCl, NaCl, KCl, and RbCl. The results indicate a variation in the Cl_2^- internuclear spacing along the series. In addition, it appears that the unpaired electron is not localized entirely on the Cl_2^- ion but has a small probability of being found on the surrounding ions. Both the reorientation temperature and the temperature at which the centers decay increase along the series; this effect may arise from the increase in lattice spacing.

* Based on work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Delbecq, Smaller, and Yuster, Phys. Rev. (to be published).

WEDNESDAY AFTERNOON AT 2:00

Physics 200

(G. M. SHRUM presiding)

Invited Papers on Earth and Cosmic Physics

J1. Rocketry. HAYDEN S. GORDON, *University of California Radiation Laboratory, Berkeley.* (30 min.)

J2. Recent Advances in Astronomy. OTTO STRUVE, *Department of Astronomy, University of California, Berkeley.* (30 min.)

J3. Some Recent Radio Evidence Concerning the Auroral Process. PETER A. FORSYTH, *Institute of Atmospheric Physics, University of Saskatchewan.* (30 min.)

WEDNESDAY AFTERNOON AT 1:30

Physics 201

(J. O. RASMUSSEN presiding)

Low-Energy Nuclear Physics II

Invited Paper

K1. Beta-Alpha Correlation in the Decay of Li^8. THOMAS LAURITSEN, *California Institute of Technology.* (30 min.)

Contributed Papers

K2. Type of Interaction in the β^- Decay of Li^8.* C. A. BARNES, W. A. FOWLER, H. B. GREENSTEIN, C. C. LAURITSEN, AND M. E. NORDBERG, *Kellogg Radiation Laboratory, California Institute of Technology.*—The final state of the Li^8 β decay is an excited state of Be^8 which breaks up into two α particles, each of energy approximately 1.5 Mev. These α particles have equal energies in the rest system of the Be^8, but in the laboratory system the energies are shifted as a result of the recoil from the β-ray and neutrino. We have measured, by magnetic analysis, the spectrum of α particles in coincidence with β rays antiparallel to the α particles. Alpha particles coincident with high energy β rays are shifted to higher energies by the recoil from the β rays, with the neutrino recoil being relatively less important, while the shift in the energy of α particles coincident with low-energy β rays is sensitive to the β-neutrino angular correlation, and hence to the type of interaction assumed for the β decay. Our data indicate that the β rays and neutrinos tend to be antiparallel. This information, together with an earlier experiment which established that the Li^8 decay is predominantly of Gamow-Teller type, suggests that the Li^8 decay proceeds mainly by axial vector coupling. These results are in agreement with recent work of Lauterjung *et al.*, on the Li^8 decay.[1]

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Lauterjung, Schimmer, and Maier-Leibnitz, Z. Physik **150**, 657 (1958).

K3. Circular Polarization of A^{37} Internal Bremsstrahlung.* L. G. MANN, J. A. MISKEL, AND S. D. BLOOM, *University of California Radiation Laboratory, Livermore.*—According to the present ideas about beta decay the internal bremsstrahlung accompanying K electron capture should be circularly polarized.[1] This has been measured in an A^{37} source produced by the $Ca(n,\alpha)A$ reaction in the MTR at Arco. Vacuum melting of the CaF_2 sample yielded 1 curie of A^{37}. The circular polarizer consisted of a magnetized cylinder of Armco iron, similar to the design of Boehm and Wapstra.[2] Radiation scattered from the inner surface of the cylinder was detected by a $1\frac{1}{2}\times 2$-in. NaI(Tl) crystal. A Cs^{137} source was used to monitor the gain of the system, which was sensitive to the magnetic field direction. The results gave $(97\pm 15)\%$ right circular polarization and yield an upper limit of $\sim 8\%$ on the ratio $|C_T|^2/|C_A|^2$. The method of calculating the polarization detection efficiency for a continuous gamma ray spectrum will be discussed.

* Work done under auspices of U. S. Atomic Energy Commission.
[1] P. C. Martin and R. J. Glauber, Phys. Rev. **109**, 1307 (1958).
[2] F. Boehm and A. H. Wapstra, Phys. Rev. **106**, 1364 (1957).

K4. Annihilation of Positrons in S, C, Cu, and Bi.† FELIX CASTILLO-JIMENEZ,* J. B. ASHE, AND W. E. MILLETT, *The University of Texas.*—The angular correlation of two-photon annihilation radiation has been studied by means of an

apparatus having conical geometry.[1] The data have been analyzed to give $N(p)$, the number of pairs which annihilate with momentum p, as a function of p. There is a noticeable difference between the momentum distributions for monoclinic and rhombic sulfur and for diamond and graphite. The curves for Cu and Bi are in agreement with previous results which indicate that for decay in metals annihilation occurs primarily with Fermi electrons. A new apparatus, using the same type of geometry but having better resolution, has been used to study oriented graphite in two positions. A slightly different $N(p)$ curve was obtained when the sample was rotated 90° about an axis perpendicular to the axis of the apparatus.

† Supported in part by the U. S. Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command.
* Recipient of an E. D. Farmer Scholarship and a special study grant from the Instituto Technológico de Monterey.
[1] W. E. Millett and R. Castillo-Bahena, Phys. Rev. **108**, 257 (1957).

K5. Decay of Positrons in Some Organic Liquids.* B. G. HOGG, *University of Manitoba*.—A delayed coincidence circuit of the Bell, Graham, and Petch[1] type was used to determine the τ_2 components in the decay of positrons in several organic liquids. The results in millimicroseconds are: glycerine 2.5±0.2, ethylene glycol 2.4±0.2, diethylene glycol 1.9±0.2, ammonia 1.7±.2, ethylene diamine 1.8±0.2, and triethanolamine 1.6±0.2. The quenching of the τ_2 component in several systems by free radicals will be discussed.

* This work was supported by the Defence Research Board of Canada while the author was at the Royal Military College of Canada.
[1] Bell, Graham, and Petch, Can. J. Phys. **30**, 35 (1952).

K6. Development of a Fast Time-Sorter for Use in the Millimicrosecond Region. J. B. WARREN AND G. JONES, *University of British Columbia*.—A time-sorter using the pulse overlap principle with a biased diode discriminator has been constructed in this laboratory for measuring lifetimes of the 10^{-10}-sec range. It is an improved version of one described by G. Jones and J. B. Warren,[1] which has an intrinsic electronic resolution time of 5×10^{-11} sec, and sufficient electronic stability to distinguish time differences of 5×10^{-11} sec over the course of several days. Measurements of the lifetimes of positrons in metals with this instrument will be described.

[1] G. Jones and J. B. Warren, J. Sci. Instr. **33**, 429 (1956).

K7. Internal Pair Angular Correlation Apparatus. B. L. WHITE AND W. C. OLSEN, *University of British Columbia* (introduced by J. B. Warren).—The multipolarity of a gamma-ray transition determines the angular correlation function $f(\theta)$ of the associated internal electron-positron pairs. Apparatus has been developed to measure $f(\theta)$ for transitions induced by particle bombardment of light nuclei. Two counter telescopes, mounted within the vacuum of the Van de Graaff accelerator, view the target. $f(\theta)$ is given by the coincidence rate between the telescopes, suitably normalized, as a function fo the angle θ subtended by them at the target. Each telescope consists of a scintillation spectrometer and a proportional counter operating in coincidence. The telescopes have a low efficiency for counting gamma rays because of the light construction of the proportional counters. The scintillation spectrometers permit the analysis of pairs produced in reactions which have complex gamma decay schemes and allow the use of fast coincidence techniques. The target, target support, and proportional counters are so constructed that scattering or external pair production in them should produce negligible distortion in $f(\theta)$.

K8. Internal Pair Angular Correlation Measurements. W. C. OLSEN AND B. L. WHITE, *University of British Columbia* (introduced by J. B. Warren).—The performance of the apparatus described in the previous paper has been established, using the 6.06 Mev electron-positron pairs from the first excited state of O^{16}, produced by bombarding CaF_2 with 850-kev protons. The energy resolution, angular resolution, overall efficiency and background effects have been measured. Results obtained with this apparatus will be described.

K9. Reactions $C^{13}+\alpha\rightleftarrows N^{14}+d$ and Time Reversal Invariance in Strong Interactions.* D. BODANSKY, S. F. ECCLES, G. W. FARWELL, M. RICKEY, AND P. C. ROBISON, *University of Washington*.—Henley and Jacobsohn[1] have suggested that a test of TRI in strong interactions can be made by a detailed comparison of the inverse reactions $C^{13}+\alpha\rightleftarrows N^{14}+d$ at equivalent center-of-mass energies. Angular distributions for these reactions have been measured using 42-Mev alphas and 20-Mev deuterons from the University of Washington cyclotron. Alpha and deuteron groups from solid targets were detected in $(\Delta E,E)$ counter telescopes using an ionization chamber +NaI and NaI+NaI, respectively. The angular distributions show strong qualitative agreement in the region 45° to 150° (c.m.). Three peaks and three valleys are observed which agree in position to within less than 2°. The relative differential cross sections agree to better than 15% except near 120° where a deep valley makes it especially difficult to obtain accurate data. It is believed that the observed discrepancies are within present experimental uncertainties. Work is continuing in an effort to substantially reduce these uncertainties and to extend the angular range.

* Supported in part by the U. S. Atomic Energy Commission.
[1] E. M. Henley and B. A. Jacobsohn, Phys. Rev. **108**, 502 (1957).

WEDNESDAY AFTERNOON AT 1:30

Physics 202

(W. N. ENGLISH presiding)

Solid-State Physics

L1. Effect of Pressure on Thermal Initiation of α-Lead Azide.* O. H. HILL† AND A. F. WITTENBORN, *Defense Research Laboratory, The University of Texas*.—The thermal initiation of detonation in alpha lead azide has been studied as a function of ambient pressure from atmospheric to hard vacuum. The thermal decomposition history of the explosive material prior to explosion has been monitored in the vacuum region. The detonation activation energy derived from the temperature coefficient of the time to explosion is found to be markedly dependent upon the gas pressure surrounding the sample; the values range from an average of 42 kcal/mole at 0.05 μ to 57.8 kcal/mole at 100 μ and 78.5 kcal/mole at 760 mm pressure. The absolute value of the time to explosion at constant temperature is also found to increase with pressure. It is suggested that the gas molecules in contact with the azide surface constitute a thermal sink which serves to reduce the magnitude of the energy fluctuations of the surface azide ions and therefore lowers the probability of these ions reacting with

positive holes trapped at the surface and thus the initiation of the nucleation reaction.

* This work was supported by Engineer Research and Development Laboratories, Fort Belvoir, Virginia.
† Now at Convair Aircraft Corporation, Fort Worth, Texas.

L2. Fluctuations in Carrier Densities in Semiconductors.* K. M. VAN VLIET AND A. VAN DER ZIEL, *University of Minnesota.*—Richardson's formalism[1] for treating diffusion fluctuations resulting from diffusion to and from the surface region. Starting from the equation,

$$(\partial \Delta p/\partial t) = -\Delta p/\tau - \mu E \cdot \nabla(\Delta p) + D\nabla^2(\Delta p) + g(r,t),$$

governing the flow of excess minority carriers of lifetime τ, mobility μ, and diffusion constant D, the problem is solved by solving an eigenvalue problem for the particular geometry. The resulting Langevin equation has been solved with the help of the Fourier method and the Ornstein method. The resulting spectrum is expressed as an infinite series with terms of the form $c_i/(1+\omega^2\tau_i^2)$.

* Work supported by U. S. Signal Corps Contract.
[1] J. M. Richardson, Bell. System Tech. J. **29**, 117 (1950).

L3. Work Hardening in Impact Deformations. MARVIN E. BACKMAN, *U. S. Naval Ordnance Test Station, China Lake, California.*—Cylindrical rods fired against plates produce indentations the depths of which are characteristic of the impact velocity and rod length. The depth of indentation is determined by an elastic relation at low velocities, by a work-hardening relation at medium velocities, and by a perfectly plastic relation at high velocities. The latter region may be interpreted as being one in which a maximum amount of work hardening is done. This is substantiated by applying an exponential law of work hardening to the indentation data for hardened steel rods in impact against 2024 aluminum alloy plates, Armco iron plates, and S.A.E. 1025 mild steel plates.

L4. A Method of Preparing Solid Ingots of Semiconducting Cadmium Antimonide. GEORGE G. KRETSCHMAR, ROY F. POTTER, AND PAUL R. BRADSHAW, *U. S. Naval Ordnance Laboratory, Corona, California.*—Early attempts at preparing the semiconductor cadmium antimonide resulted in a brittle material which fragmented easily. A method has now been developed for producing solid round bars of considerable strength. The compound occurs in two forms. It is usually a grayish hard material but sometimes occurs in a white or shiny form which is not as strong. The shiny form is converted over to the gray form on heating to a temperature less than the melting point. An x-ray analysis of the gray form has given an orthorhombic structure of 8 molecules per unit cell of dimensions $a=8.12$, $b=9.61$, $c=6.36$ A.

L5. Preparation of Polycrystalline Films of InSb. PAUL R. BRADSHAW AND ROY F. POTTER, *U. S. Naval Ordnance Laboratory, Corona, California.*—Thin layers of polycrystalline indium antimonide have been prepared by vacuum evaporation onto substrates which have been selected so as to allow infrared transmission measurements out to 15 μ. Film thicknesses varied from 0.5 to 2.0 μ. A technique has been devised for removing the film from the substrate and obtaining a Debye-Scherrer type x-ray diffraction pattern after the infrared transmissivity measurements. The d spacings for the InSb films agree with the d spacings for bulk material.[1] Different techniques and results of evaporation will be discussed. X-ray diffraction patterns will be shown for bulk and evaporated InSb.

[1] Swanson, Fuyat, and Ugrinic, Natl. Bur. Standards Circ. No. 539, (1955), Vol. IV.

L6. Optical Properties of Evaporated InSb. ROY F. POTTER, *U. S. Naval Ordnance Laboratory, Corona, California.*—Measurements at wavelengths between 1 and 15 μ, have been made of the transmission of polycrystalline evaporated indium antimonide layers. Onset of transmission was apparent at wavelengths between 1 and 2 μ, the position depending on the sample thickness. Estimates of the index of refraction, the layer thickness, and the absorption coefficient are obtained from an analysis of the interference effects. The absorption coefficient is relatively high at all wavelengths studied. Evaporated InSb exhibits characteristics which differ markedly from those of the bulk material.

L7. Impurity Band Conduction in Indium-Doped Germanium. J. S. BLAKEMORE, *Honeywell Research Center.*—Studies have been made of low temperature electrical conductivity in compensated germanium crystals, grown with indium as the major impurity and antimony as the minor. The indium densities used were sufficiently small ($3\times10^{15}-2\times10^{16}$ cm^{-3}) to ensure that conduction in the impurity band should be controlled by the degree of compensation (which ranged from 1% to 95% among the samples). The results illustrate the trapping of impurity band electrons on preferred sites at the lowest temperatures, as postulated by Price.[1] The trapping energy is some 10^{-3} ev, increasing gradually with impurity content. Mobility in the impurity band is essentially temperature independent; this varies with impurity density generally as expected from Conwell's[2] model.

[1] P. J. Price, IBM J. **2**, 123 (1958).
[2] E. M. Conwell, Phys. Rev. **103**, 51 (1950).

L8. Deformation of Aluminum at Low Temperatures and High Strain Rates. E. W. LAROCCA, *U. S. Naval Ordnance Test Station* (introduced by G. J. Plain).—The deformation of high-purity aluminum has been studied in order to determine whether shock twinning occurs in the face-centered cubic metals. To subject the metal to those conditions most likely to produce shock twinning, extremely coarse-grained aluminum samples were contained in a sleeve and subjected to an explosive load while the assembly was submerged in liquid nitrogen. The samples were later sectioned and studied by polarized light microscopy and x-ray diffraction methods. Photomicrographs in color were obtained. The deformation textures of the impulsively loaded aluminum are discussed.

L9. Infrared Absorption in Solid Li^6F^{19} and Li^7F^{19}.* A. G. STRELZOFF, R. MISHO, AND D. J. MONTGOMERY, *Michigan State University.*—Lithium fluoride was made by the reaction lof hydrofluoric acid on oxides and nitrides of separated lithium isotopes. Thin films (0.1 μ–5 μ) were evaporated onto ¾-mil polyethylene sheets. Infrared absorption spectra were obtained in the region of the infrared disperison wavelengths near 32μ by use of a modified Perkin-Elmer Model 12-C spectrophotometer with CsBr prism.†‡ The dispersion wavelengths were observed to occur as follows: Li^6F^{19}, 30.6±0.2 μ; $Li^{nat}F^{19}$, 32.6±0.2 μ; Li^7F^{19}, 32.4±0.3 μ. The values for natural LiF were the same for samples prepared by us and by Harshaw. The square of the ratio of the dispersion wavelengths for the isotopically enriched compounds is approximately the ratio of the reduced isotopic masses of the lithium ions. However, the present experimental inaccuracies are such that the ratio computed for the normal isotopic masses cannot be ruled out. It is believed that improvements in techniques of sample preparation and of observation will permit resolution of this point.

* Supported in part by the U. S. Atomic Energy Commission and the MSU All-University Research Fund.
† L. W. Hantel assisted in the preparations and measurements.
‡ Kindly made available by N. Wright and L. W. Herscher of Dow Chemical Company, Midland, Michigan.

L10. Investigation of Parameters Affecting Metal Whisker Nucleation and Growth From The Solid Phase. SAMUEL C. LAWRENCE, JR., *Boeing Airplane Company.*—Tin whiskers are

grown at 4000 times the observed spontaneous rate by rapid flexing of tin plated steel at maximum strains of 0.3%. Torsional cling of plated rods grows whiskers of cadmium, zinc, and tin. A viewing procedure has been developed which allows rapid, accurate surface scanning for whiskers. Large sets of like samples can be quickly prepared and evaluated. Statistical studies can be made and proper relative weights assigned to parameters affecting whisker growth. Some correlation is noted with parameters affecting flex and oven whisker growth. The effects of flex frequency, temperature, and amplitude; of substrate grain boundary size and preplating preparation is noted. Special plating techniques reveal differences between whisker growth from platings made in pure or contaminated baths. Tracer methods show whisker nucleation sites can be at least 6 μin. below the surface. Metallographic studies have confirmed this for pressure grown whiskers. X-ray back reflection measurements of tin "d" values show lattic strain decreasing with plating thickness, suggesting an energy source for whisker growth, and reason for increased spontaneous growth from thinner platings.

L11. X-Ray Absorption Edges of Cations in Solution. HAROLD P. HANSON, *University of Texas.*—The most significant problem in the x-ray spectroscopy of the solid state is the separation of the uniquely solid state effects from those that are characteristic of the parent atom per se. In an effort to isolate the effects which are not related to the repeating structure of the crystalline solid, K-absorption edge measurements on various compounds in solution have been made in the 1.5-A region. In general one finds that in stable complexes the edge structures do not differ for aqueous solution and the crystalline solid. This is true to energies well beyond the bound levels of the parent atom. If a Kronig type interference phenomenon produces the absorption coefficient variations out to these energies, it must be due to interference involving only the complexing anions. To the accuracy of the measurements, the edges of solvated cations in the ionic salts studied were independent of the concentration and were identical with those found in hydrated salts and in certain unhydrated salts having identical symmetry. Since the edges remain unchanged at concentrations where the transport numbers are negative, the simple complexing processs usually invoked to explain these negative numbers may not be satisfactory.

L12. Small Angle X-Ray Scattering from Cold Worked Metals.* W. T. OGIER, R. L. WILD, AND J. C. NICKEL, *University of California, Riverside.*—The double Bragg scattering calculation of Webb[1] has been extended assuming no extinction in the mosaic subgrain structure. The scattering through solid angle $d\Omega$ at small angle ϵ from an x-ray beam of flux Φ_0 incident on a cold worked polycrystalline foil of thickness t is

$$d\Phi = \Phi_0 \frac{t \exp(-\mu t) d\Omega}{8\pi\epsilon} \sum_i Q_i^2 D_i j \cot\theta_i \left[P\left(\frac{\epsilon}{2\sin\theta_i}\right) + P\left(\frac{-\epsilon}{2\sin\theta_i}\right) \right].$$

Q_i^2 is the usual powder scattering power averaged over polarization in the square, D_i the average distance traveled by the once scattered beam in the original grain, and j the multiplicity of the ith permitted Bragg plane. $P(\alpha)$ is a double probability integral, displaced by α, over the angular distribution of subgrain normals after cold work. The scattering predicted is principally from planes of small Bragg angle θ_i, is proportional to grain size and to density to the fourth power, and agrees approximately with observation.

* Supported in part by The Research Corporation.
[1] M. B. Webb, Thesis, University of Wisconsin (1956).

WEDNESDAY EVENING AT 7:00

Brock Memorial Building

(R. T. BIRGE presiding)

Banquet of the American Physical Society

After-Dinner Speech

Conferencemanship and the Scientific Understanding. DENYS H. WILKINSON, *The Clarendon Laboratory, Oxford.*

THURSDAY MORNING AT 9:30

Physics 200

(W. OPECHOWSKI presiding)

Invited Papers on Resonance and Low-Temperature Physics

M1. Some Recent Work in Molecular Beams. HIN LEW, *National Research Council, Ottawa.* (30 min.)

M2. Nuclear Resonance Experiments in Liquid and Solid He^3. WILLIAM M. FAIRBANK, *Duke University.* (30 min.)

M3. Nuclear Magnetic Resonance in Magnetic Crystals at Temperatures below 1°K. JOHN C. WHEATLEY, *University of Illinois.* (30 min.)

M4. Nuclear Spin-Lattice Relaxation in Superconducting Aluminium. ALFRED G. REDFIELD, *IBM Watson Computing Laboratory, Columbia University.* (30 min.)

THURSDAY MORNING AT 9:30

Physics 201

(K. C. MANN presiding)

Low-Energy Nuclear Physics IV

Invited Paper

N1. Elastic Scattering of 10- and 40-Mev Protons. JOHN H. WILLIAMS, *U. S. Atomic Energy Commission.* (30 min.)

Contributed Papers

N2. Alpha Particles from 32-Mev Protons on Carbons. H. B. KNOWLES, *University of California Radiation Laboratory, Livermore.*—The alpha-particle spectrum resulting from the bombardment of a polystrene target with 32-Mev protons was measured by differential range. Complete spectra were taken every 30°, and partial spectra every 15° (laboratory angles). The peaks corresponding to the reaction $C^{12}(p,\alpha)B^9$ were identified for the ground state and 2.4 Mev exited level of B^9. There was also an indication of a previously unreported level at about 7.0 Mev in B^9. The differential cross section of the (p,α) ground-state reaction shows the typical oscillatory characteristic of a medium energy reaction, and can be fitted by Butler knockon theory. If, however, the expected j_1 spherical Bessel function is used, additional interpretation is required, and j_2 yields an equally good fit; Coulomb distortion of the wave function may be the cause of this anomaly. The alpha-particle background under the peaks appeared to be caused by the direct four-body reaction $C^{12}(p;p)3\alpha$. The differential cross section for this reaction was interpreted to be anisotropic, with near symmetry around 90°. The total cross section so derived is in excellent agreement with the independently normalized data of Need.[1]

[1] J. L. Need, Phys. Rev. **99**, 1356 (1955).

N3. Reaction $T(\alpha,\gamma)Li^7$. P. J. RILEY, J. B. WARREN, AND G. M. GRIFFITHS, *University of British Columbia.*—The reaction $T(\alpha,\gamma)Li^7$ has been studied by bombarding a tritium absorbed in zirconium target with singly charged helium ions of energy 500 kev to 1.9 Mev from the U.B.C. electrostatic generator. The radiation detected corresponds to two transitions, the more intense one proceeding directly to the ground state of Li^7 while a weaker transition proceeds via the 477-kev level in Li^7, the intensity ratio being about 5:2 over the whole energy range investigated. The capture cross section rises smoothly with bombarding energy in a fashion characteristic of direct capture processes. Absolute measurements made at $E\alpha=1.64$ Mev give a differential cross section at 90° of $2\ 10^{-31}$ cm² per steradian for the ground state transition. Yield measurements at 0° and 90° to the incident beam show that the angular distribution of the radiation from the ground-state transition is not quite isotropic.

N4. Angular Distributions and Correlations for Alpha Scattering by C^{12}, Mg^{24}, Ca^{40}. G. B. SHOOK,*† *University of Washington.*—Alpha-gamma angular correlations for the 4.43-Mev level of C^{12} gave gamma distribution symmetry axes[1] θ_0 of 57°±2° and 73°±6° for target nucleus recoil directions θ_r of 49° and 65°, respectively. For the 1.37-Mev level of Mg^{24}, $\theta_0=73°\pm2$ for $\theta_r=68°$; for the 4/48-Mev level of Ca^{40}, $\theta_r=73°$, an anomalous correlation was observed, qualitatively consistent with assignment of spin and parity 1—to this level and cascade decay to ground state. Coincidence analysis of cascade gammas from a 4.48-Mev Ca^{40} level shows intermediate level is probably 3.73 Mev. Angular distributions of alphas scattered from Mg^{24} levels at 0, 1.37, 4.2, and 6.3 Mev yield effective interaction radii of 6.4, 6.55, 6.5, and 6.5, respectively (units of 10^{-13} cm). Tentative assignment of spin and parity 1− is made to the 6.3-Mev level. Ca^{40} levels at 0 and 4.48 Mev yield interaction radii of 6.65 and 6.3, respectively. The 4.48-Mev angular distribution data are consistent with spin and parity either 3− or 1−, with 1− favored on basis of correlation results. A higher level of Ca^{40} is observed at 8.4±0.1 Mev. All data are in good agreement with predictions of direct interaction theory. Incident alpha energy was 43 Mev in all cases.

* Work supported in part by U. S. Atomic Energy Commission.
† Now at Lockheed Aircraft Corporation, MSD, Palo Alto, California.
[1] M. K. Banerjee and C. A. Levinson, Ann. Phys. **2**, 499 (1957).

N5. Phase Shifts for an Alpha Particle Model of Be^8.* D. K. MCDANIELS, J. S. BLAIR, AND E. M. HENLEY, *University of Washington.*—The scattering of α particles by He has been experimentally investigated in the energy region of 0–6 and 12–22 Mev in the laboratory system, and recently the low energy phase shift analysis has been extended to 22 Mev.[1] Haefner[2] was the first to attenpt a fit of the low energy phase shifts by means of an alpha-particle model with an interaction potential which increased as $1/r^2$ at small distances. The calculation reported on here was performed in an attempt to determine whether the 0–22 Mev phase shifts could be reproduced by a simple α-α potential. The interaction chosen had an infinite repulsive central core surrounded by an attractive square well both with and without rounded outer edges. The phase shifts calculated differ from those obtained with the Haefner potential only at the higher energies considered. Both sets accounted for the qualitative energy dependence of the experimental phase shifts, but a quantitative fit was not obtained. A wider variation of the chosen interaction parameters would perhaps reproduce the observed phase shifts.

* Supported in part by the U. S. Atomic Energy Commission.
[1] For a summary of experimental data and phase shift analysis see Nilson, Jentschke, Briggs, Kerman, and Snyder, Phys. Rev. **109**, 850 (1958).
[2] R. R. Haefner, Revs. Modern Phys. **23**, 228 (1951).

N6. Alpha-Decay Amplitude and Their Phases.* LESTON W. MILLER AND BORIS A. JACOBSOHN, *University of Washington.*—A method is given for separating the resonant from the nonresonant effects in alpha decay. The latter correspond physically to Coulomb excitation (or de-excitation) of the nucleus by the alpha particle when it is outside the barrier; this most strongly affects the small $l=4$ amplitude. This effect provides all of the phase (beyond the usual Coulomb monopole phase) of the amplitudes. Semiempirical curves of the $l=4$ amplitudes as a function of mass number for even A

are presented; the imaginary part remains almost constant while the real part varies strongly, going through zero near $A=244$. A Born approximation method is used to calculate a matrix which connects the real parts of the amplitudes to the wave function on the nuclear surface. This matrix depends only weakly on the spin of the alpha emitter; its numerical value agrees well with a machine calculation[1] for Cm^{248}. It has been used to predict the real and imaginary parts of the alpha-decay amplitudes for odd-A nuclei from those for even-even nuclei. Methods of measuring the cosine and sine of the phases for odd mass nuclei will be discussed.

* Supported in part by the U. S. Atomic Energy Commission.
[1] J. O. Rasmussen and E. R. Hansen, Phys. Rev. **109**, 1656 (1958).

N7. Effects of Diffuse Nuclear Potential and the Quadrupole Interaction in Alpha-Decay Theory.* JOHN O. RASMUSSEN AND RICHARD R. CHASMAN, *University of California Radiation Laboratory, Berkeley.*—In treating the barrier penetration part of the alpha-emission process, most early treatments assumed a pure Coulombic central potential beyond a sharp cutoff in the attractive nuclear potential. Two of the most important deficiencies of such treatments result from (1) the diffuse nature of the nuclear potential in the nuclear surface region and (2) the usually large nuclear electric quadrupole moments for alpha emitters. We have calculated barrier penetrability factors and reduced widths for many alpha emitters using as nuclear potential an exponential expression for the real potential derived from optical model analysis of alpha scattering data. The penetrability integral of the simple WKB approximation was evaluated numerically between the inner and outer classical turning points using an IBM 650 computer. These calculations form the basis for a more realistic set of alpha-decay hindrance factors than have been previously available. The consequences of the quadrupole interaction with the outgoing alpha particle have been considered by many authors in recent years. Our recent work with approximate wave functions of the form of Coulomb functions multiplied by factors $(a_l+b_l r^{-1})$ will be discussed. A simple approximation for estimating the phase shifts resulting from the quadrupole interaction also will be mentioned.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

N8. Quasi-Lattice Model of Nuclear Matter. L. E. H. TRAINOR, A. B. BHATIA, AND P. C. SOOD,* *University of Alberta.*—Brueckner[1] and others[2] have applied an extension of the self-consistent method of Hartree-Fock to the determination of the properties of a hypothetical nuclear matter consisting of roughly equal numbers of neutrons and protons, the electrical forces between protons being "turned off." Taking the nucleon-nucleon interaction potentials to be those of Gammel and Thaler, we have applied the well-known Wigner-Seitz method for crystal lattices to a quasi-lattice model of nuclear matter. This method gives the energy of the lowest single particle state as a function of the internucleonic separation. One appears to obtain reasonable values for the nuclear density and the binding energy per nucleon. Justification for the quasi-lattice model and some possible implications will be discussed.

* National Research Council (Canada) Postdoctoral Fellow.
[1] K. A. Brueckner and J. L. Gammel, Phys. Rev. **109**, 1023 (1958).
[2] Gomes, Walecka, and Weisskopf, Ann. Phys. **3**, 241 (1958); H. A. Bethe, Phys. Rev. **103**, 1353 (1956).

N9. Neutron and Proton Potentials and Nuclear Forces. P. C. SOOD,* *University of Alberta.*—It was found in an earlier study[1] that the difference between the neutron and the proton potentials required to yield experimental last particle binding energies on the diffuse boundary independent particle model is proportional to the symmetry parameter $(N-Z)/A$ whereas the sum of these potentials is very nearly constant. The nucleon potentials for a wide range of individual nuclei are presented in support of the above conclusions. Following a suggestion made in that study[1] it is shown how these binding energy considerations provide an evidence for the difference between the triplet and the singlet interactions. The results are used to determine the strength of the average spin dependent interactions in nuclei and the significance of these determinations as compared to the two-body data is discussed.

* National Research Council (Canada) Postdoctoral Fellow.
[1] A. E. S. Green and P. C. Sood (to be published).

N10. rf Acceleration through the Transition Energy in an FFAG Spiral Sector Accelerator.* F. L. PETERSON, *Midwestern Universities Research Association* (introduced by K. R. Symon).—rf has been applied directly across the gap of the vacuum chamber in the spiral sector electron model. Betatron acceleration is used to stack particles at an energy somewhat below the transition energy. $(E_{trans}=m_0c^2[(k+1)^{\frac{1}{2}}-1])$ where k is the field index in the FFAG magnets. The rf is then turned on and particles are picked up and accelerated through the transition energy to their maximum energy at the outside radius of the vacuum chamber. The frequency modulation program is adjusted so that the rf is slightly higher than the particle revolution frequency near the transition energy. This is done to allow the equilibrium phase angle of the particles to change approximately 120° while crossing the unstable region in order that they may again become phase stable as they are accelerated to still higher energies. The results are analyzed using a method described by Terwilliger, Jones, and Pruett.[1] The acceleration efficiency will be described for various FM programs and the results will be compared with those predicted by the Symon and Sessler rf theory.[2]

* Supported by the U. S. Atomic Energy Commission and the National Science Foundation.
[1] Terwilliger, Jones, and Pruett, Rev. Sci. Instr. **28**, 987 (1957).
[2] K. R. Symon and A. M. Sessler, *Proceedings of the CERN Symposium on High Energy Accelerators and Pion Physics (Geneva, 1956)*, Vol. 1, p. 44.

N11. The Design and Testing of a High Power rf System for an FFAG Radial Sector Accelerator.* E. M. ROWE AND D. A. SWENSON, *Midwestern Universities Research Association.*—To obtain high current density in the stacked beam of the 40-Mev two-way electron accelerator being built at MURA, the rf system must have good amplitude and phase response over a relatively large range of frequencies and output levels. The master oscillator must be able to sweep over the required frequency range while introducing little if any phase noise. The frequency and amplitude programs must be variable with a minimum of readjustment of either the master oscillator or power amplifier. A master oscillator capable of sweeping over the frequency range between 20 and 30 Mc has been developed. Also, a linear broad-band power amplifier capable of developing 500 v across 500 $\mu\mu$f over this band has been built. The design and tests of this system will be reported on.

* Supported by the U. S. Atomic Energy Commission and the National Science Foundation.

THURSDAY MORNING AT 9:30

Physics 202

(G. L. PICKARD presiding)

Geophysics

Invited Paper

O1. Turbulence and Ocean Waves. OWEN M. PHILLIPS, *Mechanical Engineering Department, Johns Hopkins University.* (30 min.)

Contributed Papers

O2. Diffusion of Particulate Matter from an Elevated Source. K. D. HAGE, *Suffield Experimental Station, Ralston, Alberta.*—Much evidence has accumulated in recent years in support of quasi-conservation of the Lagrangian autocorrelation coefficient up to periods of the order of one minute for matter diffused from an elevated point source. On this hypothesis, a solution is found for the diffusion equation appropriate to particulate matter. The variations of the wind and the coefficient of eddy diffusion with altitude are incorporated in crude fashion in the solution. The downwind distribution curves of crosswind-integrated deposit densities of 50 μ droplets obtained in four emissions from a 15-m mast are compared with the predicted distributions and good agreement is found in the form of the curves. Extension of the work over a wide range of particulate size is indicated.

O3. Further Measurements of Turbulence in a Tidal Channel. A. M. PATTERSON, *Pacific Naval Laboratory.*—Turbulence generated in Discovery Passage over a tidal cycle has been investigated by means of constant temperature hot-wire flow meters. The main generator of the turbulence is Seymour Narrows which is situated about half way up the Passage. The turbulence in the north part of the Passage, which is wider and much deeper than the Narrows, was studied to determine the variation of the turbulence with tidal velocity and depth of the hot-wire equipment, and the decay of the turbulence with distance from the Narrows. The turbulence in the southern part of the Passage, which is wider but about the same depth as the Narrows, was also investigated and it was determined that the turbulence being generated on the sides and bottom of the Passage made up an appreciable part of the turbulence measured. Recent instrumentation developments in the problem of turbulence measurements in the ocean are also discussed.

O4. Power Input to a Wind Wave System. H. L. GRANT, *Pacific Naval Laboratory,* AND R. W. STEWART, *University of British Columbia* (introduced by W. N. English).— This paper discusses the rate at which energy is put into a system of wind waves by the sheltering mechanism and by Phillips' resonance mechanism. It is pointed out that when the dissipation of wave energy is taken into account, the resonance mechanism does not provide enough energy to account for the rate of growth of waves but that it does provide energy in parts of the spectrum where sheltering is ineffective. From order of magnitude arguments, sheltering appears to produce the necessary addition to the total energy and the spectrum of this power input is considered.

O5. Long Path Sound Fluctuation Experiment. J. E. LOKKEN, C. D. MAUNSELL, AND W. N. ENGLISH, *Pacific Naval Laboratory.*—A sound fluctuation operation was carried out in May, 1957, in deep water off the continental shelf using 32-msec 8-kc pings and ranges from 3 to more than 30 kiloyards. A towed sound source and a towed three dimensional hydrophone receiving array were used. The amount of fluctuation expressed as standard deviation over mean level is essentially independent of range at ranges over 6 kiloyards, in conformity with an interference mechanism such as that discussed by Maunsell.[1] Cross correlation for horizontal spacings is surprisingly high, being in excess of 0.9 for a spacing of 7λ while that for vertical separation is considerably lower, as was found at shorter ranges.

[1] C. D. Maunsell, Bull. Am. Phys. Soc. Ser. II, 2, 370 (1957).

O6. Geographic Variations in Geomagnetic Micropulsations. J. A. SHAND, H. J. DUFFUS, AND J. A. JACOBS, *Pacific Naval Laboratory* (introduced by W. N. English).—Differences between micropulsations observed at a fixed station near Victoria, B. C., and at a mobile field station have been studied over distances up to 30 miles. Compnents X, Y, Z of micropulsations in the frequency range 0.001 to 0.1 cycle per second and having amplitudes down to 0.1 gamma including examples of both P_c and P_t have been measured. It is found for these stations, all within ten miles of the sea, that amplitudes may differ by a factor of up to four or more, particularly in X and Z. Ratios existing between corresponding components at two stations indicate differences in both magnitude and direction. The variations tend to be greater at higher frequencies. Variations also occur over a short period of time for a particular frequency. The purpose of this work is to study the effects of environment; then to compensate for these and study the primary field in order to determine its origin.

O7. Subaudio Spectra of Magnetic Storms and Solar Whistlers. H. J. DUFFUS, P. W. NASMYTH, AND C. S. WRIGHT, *Pacific Naval Laboratory* (introduced by W. N. English).—The natural electromagnetic background in the frequency range 0.1 to 30 cps has been recorded on magnetic tape fairly continuously at Victoria, B. C., since September, 1957. The spectra of a number of magnetic storms show certain features in common in this frequency band. The ordinary daytime P_c are enhanced in amplitude. Long trains of regular oscillations having frequencies from a few tenths to a few cycles per second occur. Their frequency usually increases regularly with time. During magnetically quieter times similar oscillations occur having smaller amplitudes and frequencies which usually decrease with time. The correlation between the occurrence of these oscillations and the A index is compatible with Menzel's theory of "Solar Whistlers." However, very few have been observed since the highly disturbed months during the fall of 1957. The disturbance in this frequency range does not usually precede the commencement of the magnetic storms, as observed farther north by Maple, and therefore gives no warning of it. It sometimes coincides with the commencement. When an enhancement of

the background preceding a storm has been observed it was small and the increase was gradual.

O8. High-Energy Capacitor Discharge, Shock Tube Measurements. J. GAUGER, V. VALI, AND T. E. TURNER, *Lockheed Missile Systems Division.*—Capacitor discharge shock tube experiments have shown that the shock wave produced is a one-dimensional explosion-type wave with a nonuniform high-temperature gas behind the front. In the present experiment, an effort has been made to improve the effectiveness of the capacitor discharge drive mechanism by introducing a gas into the electrode region during the discharge. Streak photographs of the shock fronts using an image converter camera show virtually no attenuation of the shock velocity over distances of one meter. Velocities ranged from 2 to 6 cm/μsec for a capacitor bank energy spread from 2000 to 60 000 joules. Shock velocity dependence on ambient pressure, energy of capacitor system, and driving currents in the discharge have been carried out. Preliminary conclusions on ionization relaxation times will be presented.

O9. Four-Color Radiometric Temperatures of Hypervelocity Projectiles.* EARLE B. MAYFIELD, *Michelson Laboratory, U. S. Naval Ordnance Test Station, China Lake, California* (introduced by H. L. Morrison).—A radiometric method of temperature measurement described by F. S. Harris, Jr.[1] has been applied to determine temperatures of projectiles in flight. Explosive driven metal projectiles at velocities up to 3500 m/sec in air were observed. Radiation data at four wavelengths, 0.55, 0.57, 0.62, and 0.75μ, with about 10-A band pass were recorded using electron photomultiplier tubes and oscilloscopes. Time resolution for the system is about 0.1 μsec, the writing time can be varied from 1 μsec to several msec. The spectral distribution is greybody with emissivity about 0.4. Calibration was accomplished using a tungsten ribbon and optical pryometer. For aluminum projectiles in air at atmospheric pressure, the surface temperature is consistently 2050±50°K for velocities above about 2500 m/sec.

* To be offered to the University of Utah in partial fulfillment for the Ph.D. in physics.
[1] Franklin S. Harris, Jr., "Measurement of temperature in explosives," Explosives Research Group, University of Utah (August 31, 1953).

O10. γ-Ray Densitometer Studies of the Transonic Flow about a Sharp Leading Edge—Comparison of Theory and Experiment. HOWARD A. STINE, CLEO B. WAGONER, AND ALVIN L. LUGN, JR., *NACA, Ames Aeronautical Laboratory* (introduced by Hugh L. Dryden).—Density surveys of the mixed flow about the sharp leading edge of a two-dimensional lifting wedge were obtained by x-ray absorption techniques. The experiment was conducted in a closed-throat wind tunnel at choking Mach number. The Reynolds numbers ranged from 1×10^6 to 3×10^6, and the ratio of chord to tunnel height was 0.19. Data were obtained both by point-by-point surveys utilizing Geiger-Müller tubes and by exposure of x-ray film. The film data were analyzed by means of a photodensitometer which incorporated a photomultiplier tube. The density distributions as obtained by the two methods are compared in detail with theoretical results. The comparisons show that the observed flow pattern can be closely predicted by an inviscid flow solution chosen by introduction into the theory of certain simple considerations of viscosity. Comparison of the x-ray film data with that obtained with Geiger-Müller tubes shows that it is possible to obtain good quantitative density data with the film technique.

O11. Supersonic Plasma Flow along Axial Magnetic Fields.* M. EHRLICH, D. FINKELSTEIN, I. LIVINGSTON, AND D. WETSTONE, *New York University.*— Coaxial vacuum spark plasma sources up to 20 joules were fired into axial magnetic fields up to 20 kilogauss. Photographic observations were made of supersonic plasma flows under two dimensional confinement up to one meter in one- and two-inch diameter glass pipe, and various types of axial field geometries. When the flux lines were diverted or radially compressed within the tube the plasma appeared to follow the diverted lines in the manner suggested by theory.[1] Bulk plasma velocities exceeding one centimeter per microsecond were observed. Both the experimental apparatus and the data obtained will be discussed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] H. Grad, Bull. Am. Phys. Soc. Ser. II, 3, 288 (1958).

THURSDAY MORNING AT 9:00

Engineering 201

(M. SCHEIN presiding)

High-Energy Physics

P1. Depolarization of Mu Mesons in Bound States. M. E. ROSE, *Oak Ridge National Laboratory.*—The explanation of the small electron asymmetry observed in decay of μ^- and the possibility of observing neutron polarization in μ^- capture by protons depends on the polarization of the μ^- in the *ls* state. This has been investigated on the assumption that the initial orbital capture proceeds by an Auger effect followed by radiative (*El*) transitions. The results are therefore applicable to hydrogen without further assumption. The mechanism of the depolarization is twofold: spin flip radiative transitions, which must occur since capture in $j=l-\frac{1}{2}$ states are about as frequent as in $j=l+\frac{1}{2}$ states, and spin precession by the hyperfine coupling, especially in low-lying states. From a consideration of circular and nearly circular orbits as initial states it is concluded that the average μ^- polarization is less than 15% of the initial value. This result is directly applicable to observations if the depolarization in flight is negligible and if Auger scattering and exchange (which might occur in condensed media) does not occur, or does not produce appreciable spin flip transitions.

P2. Magnetic Spectrometer for 1 Bev/c Momentum.* A. V. CREWE, *University of Chicago.*—A 60° wedge focusing magnetic spectrometer with curved pole edges has been built and tested. It is to be used in studies with the 450-Mev external proton beam of the Chicago synchrocyclotron. The instrument focuses in one plane only, and has an attainable resolution of ~¼% with an available solid angle of ~1/2000 sterad. The deflection is vertical, and angular distributions can be measured from 7° to 178° without allowing the primary beam to strike the magnet yoke.

* Research supported by a joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

P3. On the Production Spectrum of Mesons in High-Energy Nucleon-Nucleon Collisions.* MARCEL SCHEIN, M. W. TEUCHER, AND D. M. HASKIN, *University of Chicago.*—In order to obtain a production spectrum of mesons in the center-of-mass system, three high-energy nuclear collisions were selected which satisfy very stringent criteria for nucleon-nucleon collisions and for which the momenta of all charged particles could be measured in the laboratory system. The results show that more than one-half of the mesons have energies less than 1 Bev in the center-of-mass system. Only a few particles emitted under very small angles in the forward and backward direction have higher energies, extending up to 10 Bev. The low-energy end of the spectrum is compared with results obtained in experiments with the Berkeley bevatron.

* Supported in part by a joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and by the National Science Foundation.

P4. Interaction Mean Free Path of High-Energy α Particles.* M. W. TEUCHER, D. M. HASKIN, E. LOHRMANN, AND MARCEL SCHEIN, *University of Chicago.*—In a stack of nuclear emulsions flown for seven hours at 102 000 ft near the geomagnetic equator at Guam (Marianas Islands) 363 alpha-particles originating in the breakups of primary heavy nuclei ($E>7$ Bev per nucleon) have been followed. Thus, 148 nuclear interactions of those alpha particles were found in an unbiased method. The resulting value of the mean free path is 20.66 ± 1.71 cm in the nuclear emulsion.

* Supported in part by a joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and by the National Science Foundation.

P5. Neutral Pion Production in Proton-Proton Collisions.* C. M. YORK, R. MARCH, W. KERNAN, AND J. FISCHER, *University of Chicago.*—A large lead glass Čerenkov counter has been used to measure the energy spectrum of gamma rays resulting from neutral pions produced in proton-proton collisions. A liquid hydrogen target was bombarded by protons at 447, 415, and 397 Mev in the external beam of the Chicago synchrocyclotron. The gamma rays emitted at 90° to the incident beam direction were detected with a counter telescope comprised of an anticoincidence counter, ½-in. lead converter, two coincidence counters, and the lead glass counter. The output of the lead glass counter was fed through a gating circuit into a 100-channel pulse-height analyzer. The three spectra obtained have been compared with those predicted by the phenomenological theory to estimate the contributions of the various possible final angular momentum states to the observed spectra.[1] A discussion of the results will be presented.

* Research supported by a joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Cf. Stallwood, Sutton, Fields, Fox, and Kane, Phys. Rev. **109**, 1716 (1958). A bibliography of earlier work is given.

P6. Production of Strange Particles and Antiparticles in Nuclear Interactions of Very High Energy ($E>10^{13}$ ev).* E. LOHRMANN AND M. W. TEUCHER, *University of Chicago.*—The production of strange particles, nucleons, and antibaryons (antinucleons and antihyperons) in nuclear collisions of an energy between 10^{13} and 10^{14} ev was studied by looking for high-energy interactions produced by the secondary particles. The ratio of secondary interactions initiated by neutral particles to those initiated by charged particles was found to be $Q=0.16\pm0.06$. Under reasonable assumptions, these data indicate that $9_{-6}^{+8}\%$ of the high-energy charged secondary particles are charged K mesons or baryons and antibaryons. The average energy of the primary collisions used in our analysis is estimated to be of the order of 10^{14} ev.

* Supported in part by a joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and by the National Science Foundation.

P7. Near-Threshold Value of π^-/π^+ Photoproduction Ratio in Deuterium. DOROTHY CARLSON-LEE, *University of Illinois* (introduced by C. S. Robinson).—A stack of G-5 pellicles was exposed to a 0.64-cm flat liquid deuterium target at 60° to a 165-Mev bremsstrahlung beam from the University of Illinois betatron. The angle between the stack and the incident mesons was 45°. Pellicles covering a meson energy bin of 6.7 to 11.7 Mev, referred to center of target, have been scanned by two observers, with total efficiencies of 0.985 for π^- stars having one or more prongs and 0.99 for π-μ decays. Over 600 mesons were found. The number of stars was corrected for 30.2% $\pm1.5\%$ of π^- stars expected to have zero prongs.[1] The measured π^-/π^+ ratio for a mean meson energy of 9.2 Mev ($\theta^*=90°$) is 2.10 ± 0.17. Applying a 13% correction[2] for Coulomb effects, a ratio of 1.83 ± 0.15 is obtained.

[1] Carlson-Lee, Stoppini, and Tau, Nuovo cimento **2**, 162 (1955).
[2] A. Baldin, preprint, "Photoproduction of π^- mesons near threshold and the value of panofsky ratio." (1958).

P8. Search for Photoproduced Mass $500m_e$ Particles.* P. E. ROSSELET AND V. Z. PETERSON, *California Institute of Technology.*—A stack of photoemulsion has been exposed to a magnetically analyzed beam of particles ($p=290$ Mev/c) emitted at 42° from a carbon target irradiated by 1.1 Bev bremsstrahlung from the C.I.T. Synchrotron. The plates, previously scanned for K^+ meson endings, were scrutinized in the region corresponding to the range of mass $500m_e$ particles. Scattering and ionization measurements were made on the tracks stopping in this area. All the tracks studied to date were produced by (1) protons and deuterons from π meson stars, (2) π mesons inelastically scattered in the plates or in the magnet pole tips, (3) μ mesons from π's decaying in flight, and (4) cosmic-ray particles. No mass was found between the π and the proton masses. If particles of mass $500m_e$ exist,[1,2] a lower limit of the photoproduction cross section is the cross section for electromagnetic pair production. A rough estimate based on a computation of the cross section for μ-meson pairs,[3] gives an expected number of 0.1 particles in the scanned volume. Therefore, our experiment does not exclude the existence of mass $500m_e$ particles, but seems to prove than its photoproduction does not exceed 10 times the Bethe-Heitler cross section. An experiment is planned with lower angle and higher Z target.

* Work supported in part by the U. S. Atomic Energy Commission.
[1] Alikhanian *et al.*, Soviet Physics JETP **4**, 817 (1957).
[2] Keuffel, Call, and Sandmann, Bull. Am. Phys. Soc. Ser. II, **3**, 162 (1958).
[3] G. H. Rawitscher, Phys. Rev. **101**, 423 (1956).

P9. Pulsed Magnetic Spectrometer for the Measurement of Photoproduction of Low Momentum K^+ Mesons.* J. O. MALOY AND V. Z. PETERSON, *California Institute of Technology.*—The short decay paths of K^+ mesons produced at backward c.m. angles by the reaction $\gamma+p\rightarrow\Lambda^0+K^+$, the low cross section, and high electron background have led us to develop a pulsed 90° magnetic spectrometer of small radius of curvature (18 cm) and large aperture (5×5 cm). The K's will have a flight path of 56 cm and will be detected in nuclear emulsion. Complete range separation is obtainable with momentum separation $\Delta p/p=0.3$ and solid angle of 0.013 steradian. Novel features of the spectrometer design are: the volume defined by the windings is a 90° section of a torus, and the windings, embedded in laminated plastic, approximate a current density $\vec{j}=\vec{H}\times\vec{n}$, where $\vec{n}$ is the normal to the torus and $\vec{H}$ is the uniform field desired inside. The field produced is uniform within 7% except at the ends. Peak fields of 60 kilogauss ($\rho c=320$ Mev) are expected, using a 30 000 joule capacitor bank; the peak current delivered will be 50 000 amp, with a half period of 800 μsec. The pulse repeats once a second. Twelve paralleled Z-5253 ignitrons are used for switching, each in series with an iron-core choke whose desaturation

time permits the ignitron to deionize when the current becomes small.

* Work supported in part by the U. S. Atomic Energy Commission.

P10. Angular Distribution of Photopions from Hydrogen for 290-Mev Photons.* V. PEREZ-MENDEZ, R. W. KENNEY, AND E. A. KNAPP. *University of California, Berkeley.*—The relative differential cross section for photoproduction of positive pions by 290-Mev photons has been measured in the angular interval from 0° to 53° (c.m.). The large electron background present in this angular region was considerably decreased by magnetically analyzing the mesons and requiring them to pass through four radiation lengths of lead placed halfway down the magnetic channel. The counter telescope used for detection utilized the characteristic π-μ decay of the meson for identification together with a Lucite Cherenkov counter to reject electrons. The relative differential cross section has a constant value (within statistics) between 0° and 30°. When this value is normalized to the data recently obtained at this laboratory in the angular region from 30° to 160°,[1] we obtain a value for the differential cross section at 0°.

$$d\sigma(0)/d\Omega = 6.9 \pm 0.58 \text{ microbarns/steradian.}$$

The data will be compared with the dispersion-relations theory of Chew *et al.*[2] for different values of the small pion-nucleon scattering phase shifts.

* Work done under the auspices of the U. S. Atomic Energy Commission.
[1] Kenney, Knapp, and Perez-Mendez, Bull. Am. Phys. Soc. Ser. II, 3, 196 (1958).
[2] Chew, Goldberger, Low, and Nambu, Phys. Rev. 106, 1343 (1957).

P11. Neutrons Produced by 910-Mev Alphas on Beryllium.* WARREN FENTON STUBBINS, *University of California, Berkeley.*—The energy spectrum of neutrons produced by 910-Mev alpha particles striking an internal beryllium target in the 184-in. cyclotron is determined from the range of protons knocked out of a scatterer by the neutrons by the use of a carbon-hydrocarbon difference. The spectrum is peaked at one quarter of the alpha energy with a high-energy tail extending to 350 Mev. The spectrum width at one-half the maximum intensity is approximately 120 Mev. The low-energy limit of the counter telescope prohibited measurements of neutrons less than 100 Mev. The data are studied by assuming that the nucleons in the alpha particle interact independently of each other during the collison with the beryllium nucleus.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

P12. Scattering of Cosmic-Ray Mesons in Cu and Pb.* ROGER ANDERSON, R. F. DEERY, AND S. H. NEDDERMEYER, *University of Washington.*—Particles selected by a simple coincidence train, and filtered through 30 in. Pb above the apparatus, traverse 1 in. Pb and 1 in. Cu in a cloud chamber with 11 000 gauss field. The chamber is in three sections 6 in. in horizontal depth and totaling 36 in. in height. Tracks are measured in space projection, and momentum and projected scattering are determined from a plot of tangent angle as a function of distance along the track. The $p\theta$ values are given by a direct measurement from the plot. Distributions of $p\theta$ for 1000 particles in the momentum interval 1–10 Bev/c which traverse both plates have been plotted and compared with the theoretical distributions calculated for mu mesons from Olbert's theory for a uniform nucleus with cutoff, and from Moliere's theory for a point nucleus. The results for Cu show a definite excess over the tail of the Olbert curve and nearly coincide with the Moliere curve, but those for Pb are only slightly higher than the Olbert curve. The excess for Cu, amounting to about 1% of the particles, is statistically significant and is regarded as further evidence for the existence of an anomalous nuclear interaction of mu mesons. The experiments are continuing in aluminum.

* Supported by the Office of Naval Research.

P13. Cosmic-Ray Interactions with Energies $\sim 10^{13}$ ev. J. G. MCEWEN,* E. PICKUP, AND R. C. KUMAR,* *National Research Council.*—In an investigation of nucleon-nucleon type interactions at very high energies two events, found recently in an emulsion stack exposed to cosmic rays in a high-altitude balloon flight, are being studied in detail. The events, of types $0+36\rho$ and $4+29\alpha$, are particularly suitable for analysis since they each have about one cm of length in each emulsion sheet, the total lengths of the showers in the stack being 11 and 24 cm, respectively. The primary energies of these jets estimated from the angular distribution of the resultant showers are 5×10^{13} and 10^{13} ev, respectively. In both events secondary electronic showers develop which cause the jets to be visible to the eye in the emulsion without magnification after several cm from the origin. Energies of some individual shower particles are deduced from secondary jets they produce. The results of measurements made so far will be presented, and their interpretation will be discussed in terms of current theories.

* NRC Postdoctorate Fellow.

P14. Flux of Lithium, Beryllium and Boron Nuclei in the Primary Cosmic Radiation. E. PICKUP, B. JUDEK, R. C. KUMAR,* AND J. G. MCEWEN,* *National Research Council.*—There is still uncertainty about the number of light primary nuclei entering the earth's atmosphere from outer space. In the present work a three liter stack of Ilford G5 nuclea: emulsions has been exposed in a balloon flight[1] for about eight hours at ceiling, 135 000 ft (residual pressure 2 g/cm^2) at Texas (~40°N). Preliminary results will be given for the relative intensities of light, medium, and heavy nuclei. This balloon flight is higher than those in previous work[2] so that less extrapolation is necessary to obtain the flux at the top of the atmosphere. It is in this correction that much of the uncertainty in the flux normally arises. Also more rigid selection criteria are being adopted, e.g., each track must be at least 1 cm in length in an emulsion sheet in the stack. In addition, the stack is of such dimensions that most of those tracks could have several interactions in the stack.

* N.R.C. Postdoctorate Fellow.
[1] The balloon flight was one made jointly for the National Research Council and the Naval Research Laboratory, Washington, by Raven Industries, Inc.
[2] See Appa Rao, Biswas, Daniel, Neelakantan, and Peters, Phys. Rev. 110, 751 (1958), for the most recent information.

P15. Interactions of Σ^- Hyperons in a Hydrogen Bubble Chamber.* RONALD R. ROSS. *University of California Radiation Laboratory, Berkeley.*—The Berkeley hydrogen bubble chamber group is currently stopping an electrostatically separated K^- beam in the 15-in. chamber,[1] with the following preliminary results. About 1400 K^- mesons produced Σ^- when they were captured by protons ($K^-+p\rightarrow\Sigma^-+\pi^+$). The momentum of these Σ^- was 174 Mev/c (12.6 Mev). Most of them decayed in flight, but 133 interacted with protons to give either primary $\Lambda(\Sigma^-+p\rightarrow\Lambda+n)$ or secondary $\Lambda(\Sigma^-+p\rightarrow\Sigma^0+n,\ \Sigma^0\rightarrow\Lambda+\gamma)$. Five of these interactions were in flight, 128 occurred after the Σ^- had gone its full range of 1.1 cm; 76 of the 133 Λ decayed by the charged mode $\Lambda\rightarrow p+\pi^-$. We made a small correction for about four more which escaped the chamber before decaying by this mode. We then found a branching fraction $\Gamma(\Lambda\rightarrow p+\pi^-)/\Gamma(\Lambda)=80/133=0.602\pm0.043$. The error should be increased slightly to account for an uncalculated error in the escape correction. Out of the 128 (primary+secondary) Λ hyperons produced when Ψ^- were captured from rest, 73 decayed by the charged

mode. For these 73 it was possible to separate the primary and secondary Λ on the basis of kinematics: 25 were secondary.

* Work done under the auspices of the U. S. Atomic Energy Commission.
[1] Horwitz, Murray, Ross, and Tripp, "450-Mev/cK^- and $\bar{p}$ beams at the bevatron northwest target area separated by the coaxial velocity spectrometer," UCRL-8269 (June, 1958).

P16. K^- Interactions at 50 to 240 Mev/c in a Hydrogen Bubble Chamber.* P. NORDIN, *University of California, Radiation Laboratory, Berkeley.*—In the experiment described in the preceding abstract, measurements have been completed of some of the in-flight interactions of K^-. The total cross section for K^- elastic scattering as a function of momentum is as follows: 50 Mev/c $<P_K$(lab) <100 Mev/c: $\sigma=36\pm15$ mb; $100<P_K<150$ Mev/c: $\sigma=66\pm11$ mb; $150<P_K<200$ Mev/c: $\sigma=67\pm8$ mb; $200<P_K<240$ Mev/c: $\sigma=38\pm9$ mb. For all elastic scatterings between 50 and 240 Mev/c, we find the following differential cross sections: $1<\cos\theta$(c.m.) <0.5: $d\sigma/d\omega=4.8\pm0.8$ mb/sterad; $0.5<\cos\theta<0$: $d\sigma/d\omega=5.6\pm0.8$ mb/sterad; $0<\cos\theta<-0.5$: $d\sigma/d\omega=5.8\pm0.8$ mb/sterad; $-0.5<\cos\theta<-1$: $d\sigma/d\omega=3.0\pm0.6$ mb/sterad. All the above cross sections have been corrected for Coulomb scattering. Σ^- production is almost isotropic and decreases with K momentum approximately as $1/v$; total cross sections are: $50<P_K$(lab) <100 Mev/c: $\sigma=112\pm28$ mb; $100<P_K<150$ Mev/c: $\sigma=23\pm7$ mb; $150<P_K<200$ Mev/c: $\sigma=21\pm5$ mb; $200<P_K<240$ Mev/c: $\sigma=15\pm6$ mb. Σ^+ production is also almost isotropic, but rises to a peak between 100 and 150 Mev/c(lab) and then falls: $50<P_K<100$ Mev/c: $\sigma=16\pm11$ mb; $100<P_K<150$ Mev/c: $\sigma=30\pm8$ mb; $150<P_K<200$ Mev/c: $\sigma=16\pm4$ mb; $200<P_K<240$ Mev/c: $\sigma=0\pm3$ mb.

* Work done under the auspices of the U. S. Atomic Energy Commission.

THURSDAY AFTERNOON AT 1:30

Physics 200

(E. A. UEHLING presiding)

Invited Papers on Solid-State Physics

Q1. New Developments in Phosphor Research. FREDERICK J. GARLICK, *University of Hull, Yorkshire, United Kingdom.* (30 min.)

Q2. Nuclear Magnetic Resonance in the Alkali Halides. N. BLOEMBERGEN, *Cruft Laboratory, Harvard University.* (30 min.)

Q3. Nuclear Magnetic Resonance and Line Shapes in Solids. RICHARD E. NORBERG, *Washington University.* (30 min.)

Q4. One-Dimensional Impurity Bands. MELVIN LAX, *Bell Telephone Laboratories, Inc.* (30 min.)

THURSDAY AFTERNOON AT 1:30

Physics 201

(F. H. SCHMIDT presiding)

Low-Energy Nuclear Physics V

R1. Critical Mass of a Nuclear Reactor by Multigroup Richards' Approximation. RICHARD L. MOORE.*—Richards[1] method in multigroup form for neutron transport problems as previously developed[2] has been simplified. The computation of the critical concentration is done by assuming that the fission-density function may be approximated to the desired accuracy by the sum of positive even functions, $F_i(r)$ multiplied by the weighting factors S_i. A trial flux is computed assuming the assembly to be critical. The computation results in trial values for S_i. If the assembly is not critical, the trial fission density function will be negative somewhere, giving a *reductio ad absurdum* proof that the assembly is not critical. By suitable choice of the functions $F_i(r)$, the critical concentration is reached when $\Sigma a_{ij}S_i \geq 0$. Because of the matrix formulation of the problem and because the only iterations necessary for a given geometry are those necessary to determine the critical concentration in the multiplying region, it is expected that this method will be faster than many others of comparable accuracy in current use.

* Consultant, P. O. Box 2401, Los Angeles 24, California.
[1] Paul H. Richards, Phys Rev. 100, 517 (1955).
[2] Richard L. Moore, Bull. Am. Phys. Soc. Ser. II, 2, 311 (1957).

R2. Elastic Scattering of Fast Neutrons by Calcium.* L. CRANBERG, J. D. SEAGRAVE, AND J. E. SIMMONS, *Los Alamos Scientific Laboratory.*—In the course of measuring n-T scattering with CaT_3 and Ca samples, as described elsewhere in this Bulletin, differential cross sections were obtained for the scattering by calcium of neutrons at $E_n=1.0$, 2.0, 3.5, and 6 Mev. These are in qualitative agreement with the optical-model calculations of Beyster *et al.*[1] An auxilliary measurement of the total neutron cross section of calcium was made for use in the multiple-scattering calculations. The results are listed here in the form σ_T(barns)/E_n(Mev): 2.87/1.0, 2.71/1.5, 3.16/2.0, 3.52/2.5, 3.76/3.0, 3.87/3.5, 3.85/4.0, 3.66/4.5, 3.42/5.0, and 3.16/6.0. The "size resonance" near 4 Mev is sharper and higher than the calculations suggest, or than is the case for the neighboring elements iron and titanium.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] J. R. Beyster, Los Alamos Report LA-2099 (unpublished).

R3. Thermal Neutron Capture Cross Sections of Er^{166} and Er^{167}. G. R. HOPKINS, *Westinghouse Electric Corporation.**—A critical assembly was used with the "danger coefficient"

technique to measure the thermal neutron capture cross sections of Er^{166} and Er^{167}. Enriched samples† were compared with natural Er ($\sigma = 166$ b)[1] to obtain their capture areas. The sample enrichments in atom percent were

Isotope	162 and 4	166	167	168	170
Sample 1	<0.1	72.9	17.7	8.5	0.8
Sample 2	<0.1	14.0	58.8	25.3	1.93.

The equations relating the isotopic cross sections to capture area are of the form $\Sigma_i N_{ij}\sigma_i = A_j$ where N_{ij} is the total number of atoms of isotope i in sample j, σ_i the isotopic capture cross section and A_j the sample j capture area. The accuracy of measured values of A_j were $\pm 3\%$. Using $\sigma(Er^{166}) = 2$ b and $\sigma(Er^{170}) = 9$ b[1] for thermal capture, solution of the equations yielded $\sigma(Er^{167}) = 620$ b and $\sigma(Er^{168}) = 45$ b. These are 2200 m/sec values and are expected to be accurate to $\pm 20\%$, based on the natural erbium cross section uncertainty of $\pm 10\%$ and the assumption that the resonances are distributed among the isotopes in the ratio of their thermal cross sections.

* U. S. Atomic Energy Commission contract.
† Oak Ridge, Isotope Sales Department.
[1] W. H. Sullivan, Oak Ridge, Trilinear Chart of Nuclides, January, 1957.

R4. Inelastic Scattering of 14-Mev Neutrons from Carbon and Beryllium.* J. D. Anderson, C. C. Gardner, M. P. Nakada, and C. Wong, *University of California Radiation Laboratory, Livermore.*—The angular distributions of the neutrons from the reactions $Be^9(n,n')Be^{9*}$, $Q = -2.43$ Mev and $C^{12}(n,n')C^{12*}$, $Q = -4.43$ Mev have been measured from 25° to 140° employing 14-Mev incident neutrons. Neither distribution is symmetric about 90°; the inelastic neutrons are peaked in the forward direction. The $C^{12}(n,n')C^{12*}$ first level angular distribution, which agrees with a recent measurement of the $C^{12}(p,p')C^{12*}$ distribution, is in good agreement with the prediction of the Levinson-Banerjee direct interaction theory. The integrated inelastic cross sections for the Be^9 and C^{12} first levels are 0.17 ± 0.03 b and 0.22 ± 0.03 b, respectively. The 4.43-Mev de-excitation gamma rays from C^{12*} are symmetric about 90°. The gamma production cross section at 90° is 13.1 ± 2.0 mb/ster. No gamma rays associated with Be^{9*} are seen. It is concluded that about one-third of the $Be^9(n,2n)$ cross section at 14 Mev is a two stage process proceeding via the 2.43-Mev level in Be^9.

* Work done under the auspices of the U. S. Atomic Energy Commission.

R5. 14-Mev $(n,2n)$ Cross Sections of F^{19}, Cu^{65}, Zn^{64}, Ga^{69}, Mo^{92}, Sb^{121}, and Pr^{141}.* L. A. Rayburn, *Argonne National Laboratory.*—The $(n,2n)$ cross sections of the above named nuclides have been measured using an activation technique. The two 0.511-Mev gamma rays from annihilation of the positrons from the activated samples are counted in coincidence by using two NaI scintillation spectrometers. The percentage of the decays that take place by positron emission must then be known in order to compute the values of the cross sections. The psoitron decay percentages that were used are given in Table I. A value of 500 mb (the weighted mean of several published values) was used for the cross section for the $Cu^{63}(n,2n)Cu^{62}$ reaction in order to convert the measured relative cross sections to absolute cross sections.

Table I.

Nuclide	Half-life	$(n,2n)$ cross section mb	Positron decay percentage
F^{19}	1.85 hr	51.3	97.1
Cu^{65}	13.4 hr	935	19.0
Zn^{64}	39.9 min	159	89.8
Ga^{69}	69.2 min	1089	83.5
Mo^{92}	15.2 min	188	94.0
Sb^{121}	15.7 min	1000	43.7
Pr^{141}	3.27 min	1768	58.0

Preliminary values of these absolute cross sections are given in Table I.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

R6. Neutron Cross-Sections of Five Isotopes of Dysprosium. L. L. House* and R. T. Frost, *Knolls Atomic Power Laboratory.*†—Thermal cross sections of the abundant isotopes of sysprosium were measured using a pile oscillator in a critical assembly with a neutron temperature of 0.0265 ev. Danger coefficients for thin samples of enriched isotopes[1] were compared with coefficients measured for Argonne-Brookhaven standard boron. The Dy_2O_3 samples were finely dispersed in aluminum powder. The oscillating component of the neutron flux was detected with a BF_3 chamber and a high Q galvanometer tuned to the oscillator frequency, allowing measurements to be made with an accuracy limited primarily by pile noise. Measurements carried out with several sample thicknesses allowed extrapolation for the unshielded danger coefficients and the linear equations representing the extrapolated measurements for the dysprosium mixtures were solved for the unshielded isotopic cross sections. Experiments were performed using cadmium shields to allow corrections for resonance absorption, thus yielding the 2200 m/sec cross sections in Table I.

Table I.

	Dy^{164}	Dy^{163}	Dy^{162}	Dy^{161}	Dy^{160}
σ^{total}	2780±50	220±50	240±30	680±40	130±130 barns
$\sigma^{thermal}$	2750±150	120±50	140±40	580±50	...

* Now at University of Colorado High Altitude Observatory.
† Operated by the General Electric Company for the U. S. Atomic Energy Commission.
[1] The separated isotopes were obtained from Oak Ridge National Laboratory.

R7. Prompt Neutron Emission from Single Fission Fragments of Known Mass. Stanley L. Whetstone, Jr., *Los Alamos Scientific Laboratory.**—With a Cf^{252} source placed at the edge of a large cadmium-loaded liquid scintillator it has been possible to obtain a measure of the number of prompt neutrons emitted from a single fission fragment of known mass. The mass determination results from a simultaneous time-of-flight measurement of the two fragment velocities. A good distinction between the neutrons emitted from a fragment passing through the scintillator (in an evacuated tube) and those neutrons emitted by the complementary fragment is provided by the strong correlation between the directions of the emitted neutrons and the fragments.[1] The 30-in. scintillator gives a high detection efficiency, little dependent on the energy of the neutrons, and permits detection in a full hemisphere about the direction of one of the fragment flight paths. The experimental equipment has been described.[2] Very preliminary data indicate an increase in neutron emission probability from the light fragments as the symmetric mass mode is approached.

* This work was done under auspices of the U. S. Atomic Energy Commission.
[1] J. S. Fraser, Phys. Rev. **88**, 536 (1952); J. S. Fraser and J. C. D. Milton, Phys. Rev. **93**, 818 (1954).
[2] W. E. Stein and S. L. Whetstone, Jr., Phys. Rev. **110**, 476 (1958).

R8. Energy Dependence of Fission Anisotropy,* James J. Griffin, *Los Alamos Scientific Laboratory.*—It is shown that A. Bohr's[1] theory of the anisotropy of fission fragment emission is capable of explaining qualitatively the energy dependence of anisotropy in neutron induced fission, if only reasonable assumptions are made about the energy dependence of the maximum value of K, the component of angular momentum along the nuclear symmetry axis. In Th^{232}, for example, the sudden increase in W_0/W_{90} just above the $(n,n'f)$

threshold[2] is attributed to "second chance" fissions which occur through states of high total angular momentum and relatively low excitation energy (low K). Calculations are presented for Th^{232} based on Bohr's classical limit. Caluclations are also presented for the case of $Pu^{239}+n$ at low energy. The spin ($\frac{1}{2}$) of Pu^{239} is neglected, but the low-energy anisotropy[3] is still given qualitatively, suggesting that the target spin becomes a secondary effect when the incoming orbital angular momentum of the neutron is somewhat larger than the target spin. Comparison is made in this case with the data for U^{235} (spin $=\frac{7}{2}$) where the anisotropy is suppressed[3] for $E_n<3$ Mev.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] A. Bohr, Proc. Intern. Conf. Peaceful Uses Atomic Energy, Geneva **2**, 151 (1955).
[2] R. Henkel and J. Brolley, Phys. Rev. **103**, 1292 (1956).
[3] Simmons, Henkel, and Brolley, Bull. Am. Phys. Soc. Ser. II, **2**, 308 (1957).

R9. Elastic Scattering of Fast Neutrons by Tritium.* J. D. SEAGRAVE, J. E. SIMMONS, AND L. CRANBERG, *Los Alamos Scientific Laboratory.*—Differential cross sections have been obtained for the elastic scattering of neutrons by tritium at $E_n=1.0$, 2.0, 3.5, and 6.0 Mev, over the angular range 27° to 161° in the c.m. system. The Los Alamos large Van de Graaff accelerator and pulsed-beam time-of-flight facility were employed, and 1.6 g of tritium was prepared in the form of CaT_2, contained in a thin-walled stainless steel sphere $1\frac{1}{4}$ in. in diameter. An identical cell containing calcium and an empty cell were used to distinguish the contributions from tritium, calcium, and steel. Cross sections were determined by comparison with the scattering from a thin shell of CH_2 at each energy, together with calibration of the relative sensitivity as a function of energy with the known forward yield of the $T(p,n)He^3$ reaction. The angular distributions for n-T scattering are in good agreement with the calculations of Bransden *et al.*[1] based on a Serber exchange force. However, the experiments show somewhat less pronounced backscattering than predicted for the higher energies.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Bransden, Robertson, and Swan, Proc. Phys. Soc. (London) **A69**, 877 (1956).

R10. Elastic Scattering of Fast Neutrons by He^3.* J. E. SIMMONS, L. CRANBERG, AND J. D. SEAGRAVE, *Los Alamos Scientific Laboratory.*—Differential cross sections have been obtained for the elastic scattering of neutrons by He^3 at $E_n=1.0$, 2.0, 3.5, and 6.0 Mev over the angular range 27° to 161° in the c.m. system. The n-He^3 scattering was measured in the same manner as the n-T scattering described in the preceding abstract. The apparatus differed in that the He^3 was contained at 5,000 psi in a 0.035-in. wall steel sphere of 1.5-in inside diameter, and only one dummy cell was required. For both experiments self-absorption and multiple-scattering corrections were calculated by the Monte Carlo method. The n-He^3 measurements favor qualitatively the Serber exchange force used in the calculations of Bransden *et al.* The agreement is poorer than that obtained for n-T scattering. At 3.5 and 6-Mev n-He^3 scattering shows less pronounced backscattering than predicted for the Serber force, at 2 Mev there is stronger forward scattering than predicted, and at 1 Mev the scattering is similar in shape, but has nearly twice the predicted cross section. The n-He^3 scattering at 6 Mev is much more strongly forward than the p-He^3 results of Sweetman[1] at 5 Mev.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] D. R. Sweetman, Phil. Mag. **46**, 358 (1955).

R11. Elastic, Inelastic, and Reaction Scattering of 21-Mev He^3 Ions.* H. E. WEGNER AND W. S. HALL, *Los Alamos Scientific Laboratory.*—The angular distributions for 21-Mev He^3 ions elastically scattered from Nb, Ni, Ti, Al, and C have been measured. Inelastic groups have been observed in Ni and Nb similar to the proton spectra observed by Cohen.[1] The inelastic angular distribution from the 4.43-Mev level of carbon has been measured. The following reaction scattering angular distributions have been investigated for a number of levels in each case: $C^{12}(He^3,\alpha)C^{11}$, $C^{12}(He^3,d)N^{13}$, $C^{12}(He^3,p)N^{14}$ and $Be^9(He^3,t)B^9$. The general characteristics of each are a strong forward peaking and the usual diffraction-type angular distribution. Comparisons of this work with theory will be discussed. The dE/dX and E particle identification system[2] and scattering chamber will be briefly described. The He^3 beam characteristics are as follows: internal beam ~1000 μamp, external beam ~100 μamp. The operating characteristics of the He^3 recirculation and purification system supplying the ion source of the Los Alamos variable energy cyclotron will be described.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] B. L. Cohen, Phys. Rev. **105**, 1549 (1957).
[2] Stokes, Northrop, and Boyer, Rev. Sci. Instr. **29**, 61 (1958).

THURSDAY AFTERNOON AT 2:00

Physics 202

(R. GEBALLE presiding)

Low-Temperature Physics

S1. Kinetics of Phase Transitions in Superconducting Aluminum.* K. L. CHOPRA AND T. S. HUTCHISON, *Royal Military College.*—The kinetics of the phase transition in superconducting polycrystalline aluminum have been studied by measurement of the ultrasonic attenuation as a function of time. The total time taken for the destruction of the superconducting phase in a cylindrical specimen of radius r by means of a magnetic field H greater than the critical field H_c is approximately proportional to $r^3\,H/(H-H_c)$, in agreement with the eddy current theory. The rate at which the superconducting phase collapses is uniform in thin specimens and is a function of H and H_c. In a thick specimen, (diameter 30 mm, length 40 mm) steps corresponding to different rates of collapse have been observed. In the converse case, where the superconducting phase is restored by switching off the magnetic field $H>H_c$, the total time taken is almost independent of temperature (or H_c) as well as H. The rate of growth of the superconducting phase is not uniform, and is less than the rate of collapse by a factor of at least 10.

* Supported by Defense Research Board of Canada, Grant, No. 7510-14 Project No. D44-75-10-14.

S2. Effect of a Magnetic Field on Thin Superconducting Lead Films.* DONALD M. GINSBERG† AND M. TINKHAM, *University of California, Berkeley.*—Some of the effects of a magnetic field on a 20 A superconducting lead film at 1.5°K

have been observed. The magnetic field was in the plane of the film, and was 8000 gauss. Although this is about ten times the critical field for bulk samples of lead, it has only a small effect on a thin film. The field lowered the critical current of the film by 2%. The transmission of far infrared radiation through the film was measured. The film was then completely oxidized and the run repeated, to correct for a small field dependence of the sensitivity of the detector, which was a carbon resistance bolometer. The data have been analyzed to find the behavior of the real and imaginary parts of the conductivity.[1] It is found that the field changes the width of the energy gap by less than 2% and the penetration depth by less than 1%. The bolometer detector has also made possible a more precise estimate of the width of the energy gap than has previously been possible with this type of experiment.

* Supported in part by the National Science Foundation and the Office of Naval Research.
† Predoctoral National Science Foundation Fellow.
[1] R. E. Glover, III, and M. Tinkham, Phys. Rev. **108**, 243 (1957).

S3. Evidence for a Density Maximum in Liquid He^3 near 0.5°K.* D. M. Lee, J. D. Reppy, and Henry A. Fairbank, *Yale University.*—A study of the convective heat transport in liquid He^3 indicated a negative expansion coefficient below 0.5°K and a positive expansion coefficient above about 0.6°K. A pycnometric measurement of the density was made which showed a maximum at approximately 0.5°K. In view of the Maxwell relation $(\partial S/\partial P)_T = -(\partial V/\partial T)_P$ this implies that the entropy of liquid He^3 increases with pressure below 0.5°K. An apparatus has been constructed to measure the dielectric constant and hence the density of He^3 below 1°K under its saturated vapor pressure and at elevated pressures. Preliminary measurements performed with this apparatus also give indications of a density maximum in liquid He^3. Results of further measurements using this technique will be reported.

* Assisted by the Office of Ordnance Research and the National Science Foundation.

S4. Lambda Transition and Phase Separation Temperatures in Superfluid He^3-He^4 Mixtures under Pressure.* S. D. Elliott, Jr., and Henry A. Fairbank, *Yale University.*—The velocity of second sound has been measured in superfluid He^3-He^4 mixtures of 15.6, 30.4, and 48.7 mole percent He^3 content over the temperature interval between 0.2°K and the respective lambda points at pressures ranging up to approximately 25 atmos. The temperatures at which the normal superfluid (lambda) and single phase-two phase[1] transitions occur have been determined from these measurements; both transition temperatures are found to fall with increasing He^3 concentration and increasing pressure. Detailed results are presented, and their implications are discussed.

* Assisted by the National Science Foundation and the Office of Ordnance Research.
[1] G. K. Walters and W. M. Fairbank, Phys. Rev. **103**, 262 (1956).

S5. First Adsorbed Layer of Helium. J. P. Hobson, *National Research Council.*—The adsorption isotherm of helium on Pyrex glass (Corning 7740) at 4.2°K has been measured for pressures above the adsorbed helium layer ranging from 10^{-4} mm Hg to 10^{-12} mm Hg. Ultra-high vacuum techniques were used for the measurement with geometric adsorbing areas approximately 30 cm^2. Below a pressure of about 8×10^{-10} mm Hg the amount adsorbed was proportional to pressure above the adsorbed layer. Above 8×10^{-10} mm Hg a distinct plateau in the isotherm was observed which matched, within a factor 2 in the region of overlap, the results given by Meyer[1] for helium adsorption on gold foil at 4.2°K. At 8×10^{-10} mm Hg approximately 3×10^{14} atoms of helium were adsorbed per square centimeter of geometric surface. It is proposed that this point represents the completion of the first physically adsorbed layer of helium at 4.2°K.

[1] Lothar Meyer, Phys. Rev. **103**, 1593 (1956).

S6. Molecular Surface Velocity of Liquid Helium. Leonard S. Levitt, *Stevens Institute of Technology.*—Dimensionally, surface tension divided by viscosity is a velocity. From the magnitude of this quantity for various liquids at various temperatures, γ/η is apparently the translational velocity of the molecules in the surface. For liquid He at its boiling point (4.22°K), $\gamma/\eta = 25$ m/sec. This velocity increases linearly with decreasing temperature to 95 m/sec at 2.5°, and then increases markedly through the λ point (2.18°), becoming 260 m/sec at 2.0° and 280 m/sec at 1.5°. The value of γ/η extrapolated from the linear plot (between 4.2 and 2.5°) is 195 m/sec at 0°K. These values are similar in magnitude to the velocity of sound in liquid He (which also increases with decreasing T), to the velocity of "second sound," and to the estimated "zero-point" velocity (166 m/sec). A lower limit must be placed on the viscosity of He II; it cannot become zero at 0° if γ remains finite, since $\eta > \gamma/c$, where c is the velocity of light. This *lower* limit, assuming $\gamma \approx 0.3$ dyne/cm, is 10^{-11} poise, which has previously been estimated as the *upper* limit. The thickness of an He surface is calculated to be $d \approx h\eta/2\pi\gamma m = 6$ A at 4.22° and about 1 A at 0°.

S7. Noise Spectrum of Ball-of-Fire Thyratrons. A. R. Galbraith, A. van der Ziel, and K. M. van Vliet, *University of Minnesota.*—Noise measurements of "ball-of-fire" thyratrons indicate a huge amount of noise (about 0.1 amps of rms noise current at a tube current of 5–10 amps). The spectrum is flat at low frequencies, shows a dip at about 50 kc, a peak at about 130 kc, and drops as $1/f^4$ at higher frequencies. The equivalent circuit of the tube is an LR series circuit with the noise represented by a noise current generator $(i^2)_{Av}$ in parallel to R. The observed spectrum can be explained if the noise current generator is attributed to independent random damped oscillation of the form $\exp[-\alpha(t-t_0)]\cos\omega_0(t-t_0)$.

S8. Quantum Theory of Linear Dissipative Systems.* R. W. Hellwarth, *Hughes Research Laboratories.*—In certain devices currently of interest, such as quantum mechanical amplifiers, a detector is linearly coupled to a network of linear elements such as molecules, cavities, antennae, and resistances. A formal expression has been derived for the transition probabilities of any detector coupled to a linear network. This expression is a function of the detector coordinates and states only. Feynman's ordered operator calculus[1] in which the order of operations is indicated by subscripts (so that operator functions can be manipulated like ordinary functions) is employed to eliminate the network operator variables from the detector probability expression. Terms in this expression can be identified as circuit impedances, signal, and noise. When the detector is driven at a classical level, the results agree with conventional "maser" noise calculations to give a minimum obtainable amplifier noise temperature. The spontaneous emission probability of any particle coupled to a network is seen to be proportional to the classical input network conductance calculated at the emission frequency. Applications to other linear systems are suggested.

* Supported in part by the U. S. Signal Corps, Fort Monmouth, New Jersey.
[1] R. P. Feynman, Phys. Rev. **84**, 108 (1951).

S9. Approach to a Theory of Variable Temperature Heat Baths Using Electrical Analogies.* R. C. Sill,† *Stanford Research Institute.*—Analogies between thermal and electrical quantities can be used to reduce complicated thermal diffusion

problems to more familiar electrical circuits.[1] These analogies are applied to some static and dynamic thermal problems. As one example the equivalent electric circuit of a large heat bath system involving (a) the bath (189 liters) having no heat sources, (b) an external heat exchanger circuit containing the system control and the heat sources, and (c) a controlled environment separated from the bath by a paraffin-oil layer is set up and solved subject to the following conditions: (1) The bath is initially at a constant temperature; then the control causes the average temperature in the heat exchanger to rise steadily. (2) A step function is inteoduced into the heat exchanger, and the response time of the bath is determined. Comparisons are made between theory and experiment. A response time of 170 min is found for a bath whose fluctuations are to be reduced to the order of 10^{-4} °C. Changes of 0.6°C in the environment produce changes of 10^{-3} °C.

* This work was supported by the Stanford Research Institute Development Committee.
† Now at New Mexico Institute of Mining and Technology, Socorro, New Mexico.
[1] For example see McMaster, Merrill, and List, Prod. Eng. **184** (1953).

S10. Separation of Gases by Diffusion in Silica Glass. K. B. McAfee and G. T. Kohman, *Bell Telephone Laboratories.*—Studies of glass structure and its relationship to gaseous permeability have indicated an application to the separation of gaseous mixtures. Separation is possible because the random network structure of silica glass is sharply selective towards atoms and molecules having diameters between 2 and 4 A. Diffusion through glass is especially effective for separating mixtures containing helium hydrogen isotopes, and neon in heavier gases. Two observations made in this investigation have been employed in the development of the method which results in a new approach to the problem of helium recovery. One of these observations is the highly selective nature of gaseous diffusion through glass and the other is the high compressive strength of thin walled silica glass capillaries which appears to be related to the extremely high tensile strength reported for fine glass fibers. Results are presented on the separation of helium from synthetic mixtures and from natural gas samples. The separated gas contains no detectable impurities—such purity being of importance in gas filled electron tubes and where an extremely inert atmosphere is required such as at semiconductor surfaces. The rates of separation and purification of an experimental diffusion cell will be discussed. A direct determination of the diffusion constant D of helium and other gases in silica has been made, as well as a separate determination of the solubility.

S11. Some Numerical Relations between the Constant P' and Other Magnitudes. N. Efremov, *New York, New York.*—The initial constant $P'(=0.0109677$ A) proposed* by us for calculation of ionic and atomic radii is connected with other magnitudes by remarkable relations,

(1) Our constant	$P'=0.0109677$ A	0.0109677 A	$=P'$
(2) Rydberg constant	$R=0.00109677$ A^{-1}	0.00109677 A	$=0.0109677\times10^{-1}$
(3) The third unit	0.0001 A	0.0001 A	$=P'\times10^{-2}$: 1.09677
(4) "Basic length unit"	0.00001 A	0.00001 A	$=P'\times10^{-3}$: 1.09677.

The third unit is close to the value of the nuclear radii of heavy (U, Ra, Th) elements. The fourth unit is 0.000 000 000 001 mm and coincides with the constant (=0.000 000 000 001 mm) recently postulated by W. Heisenberg.

* N. Efremov, Phys. Rev. **94**, 753(A) (1954).

SUPPLEMENTARY PROGRAMME

SP1. *V-T* Relationship for Gases and Liquids at Extreme Pressures.* Leonard S. Levitt, *Stevens Institute of Technology.*—It has been shown[1] previously that, at extreme pressures (10^3 to 10^5 Kg/cm^2), gases, liquids, and solids all obey the same isothermal P-V relation, $P=Ce^{B/V}$, where B and C are constants characteristic of the particular substance. It is now found, using Bridgman's data for H_2O, N_2, and A, that the V-T isobars, though curved at medium pressures, become good straight lines[2] at the same higher pressures for which the P-V relation begins to hold (above 1000 Kg/cm^2 for gases, and above 5000 for liquids[1]). Aside from the surprising linear variation of V with T under these extreme conditions, the most remarkable feature of the V-T plots is the apparent convergence of all the isobars (for a given substance) to a common intefcept on the V coordinate (at 0°K). The isobars therefore can be represented by the equation, $V=V_0+a_pT$, where V_0 is the molar volume of the substance at 0°K, and $a_p=(\partial V/\partial T)_p$ (a_p decreasing with increasing P). The V_0's are about 25% smaller than Van der Waals's "b."

* To be given after Session F if the Chairman rules that time permits.
[1] L. S. Levitt, J. Phys. Chem. **58**, 573 (1954).
[2] A linear variation of V with T at extreme pressures was observed recently for high molecular weight hydrocarbons. Cutler, Webb, and Schiessler, Bull. Am. Phys. Soc. Ser. II. **3**, 232 (1958).

SP2. A Rydberg-Type Formula for the Mass Spectrum of Elementary Particles.* Leonard S. Levitt, *Stevens Institute of Technology (Chemistry Department).*—A formula analogous in all respects to the Rydberg formula for the hydrogen spectrum is capable of reproducing the masses of nearly all the known elementary particles. This true "mass spectrum" formula can be written, $M=n_0^2M_0(1/n_a^2-1/n_b^2)$, where M is the mass (in units of electron masses) of the desired particle, $M_0=2452$[1]; $n_0=1$ or 2; $n_a=1$, 2, 3$\cdots$; and $n_b=n_a+1$, $n_a+2,\cdots$. Table I gives the values the n's must have to reproduce the particle masses, and also compares the calculated and observed mass values.

Table I.

Particle	n_0	n_a	n_b	Calc mass	Obs mass
$\mu^\pm$	1	3	6	204	207
$\pi^\pm$	1(2)	3(5)	∞(9)	272	273
A^+	1	2	6	545	550
$\pi^\pm$; ϕ^0	2	3	9	968	966; 965
p^+; n^0	1	1	2	1839	1836; 1839
Λ^0	1	1	3	2180	2181
Σ^+	1	1	4	2301	2327
Σ^-	1	1	5	2353	2342

* The symbol A is used here for Alikhanian's particle, recently confirmed by Keuffel, Call, and Sandmann. Bull. Am. Phys. Soc. Ser II, **3**, 162 ((1958).
* To be given after Session F if the Chairman rules that time permits.
[1] This same mass was predicted also by the author's previous and completely different formula for the particle masses. L. S. Levitt, Bull. Am Phys. Soc. Ser. II, **3**, 175 (1958); also Current Sci. (India) **27**, 131 (1958).

Author Index to Papers Presented at the Vancouver Meeting

Alger, R. S.—E2
Allison, Samuel K.—F8
Anderson, A. G.—I1
Anderson, J. D.—R4
Anderson, Roger—P12
Armstrong, B. H.—F6
Aroeste, Henry—F2
Artman, J. O.—E1
Ashe, J. B.—K4
Backman, Marvin E.—L3
Ball, J. B.—H6
Barnes, C. A.—K2
Bedford, R. E.—F10
Bell, W. E.—I10
Bhatia, A. B.—N8
Bjorkstam, John L.—E3
Blair, J. S.—N5
Blakemore, J. S.—L7
Bloembergen, N.—E1, Q2
Bloom, A. L.—I10
Bloom, M.—I2
Bloom, S. D.—K3
Blumberg, W. E.—E4
Bodansky, D.—K9
Bowers, K. D.—I9
Bradshaw, Paul R.—L4, L5
Brockhouse, Bertram N.—D4
Carlson-Lee, Dorothy—P7
Castillo-Jimenez, Felix—K4
Chasman, Richard R.—N7
Chopra, K. L.—S1
Christofilos, Nicholas, C.—A2
Christy, Robert F.—D1
Chupp, E. L.—B3
Cochran, D. R. F.—H8
Cork, Bruce—G1
Cowen, J. A.—I7
Cranberg, L.—R2, R9, R10
Crewe, A. V.—P2
Crooker, A. M.—F10, F11
Csavinszky, P.—F3
Dalitz, Richard H.—G2
Daniels, J. M.—I8
Dawson, W. K.—H11, H12, H13
Deery, R. F.—P12
Delbecq, C. J.—I12
DeWitt, Hugh E.—F9
Dransfeld, K.—I5
Duffus, H. J.—O6, O7
Dumond, J. W. M.—B3
Dunbar, D. N. F.—H3
Eccles, S. F.—K9
Efremov, N.—S11
Ehrlich, M.—O11
Elliott, Jr., S. D.—S4
Emshwiller, M.—E5
English, W. N.—O5
Ewbank, W. Bruce—E10
Fairbank, Henry A.—S3, S4
Fairbank, William M.—M2
Fairhall, A. W.—H6
Farwell, G. W.—K9
Fink, R. W.—H1, H2
Finkelstein, D.—O11
Fischer, J.—P5
Fleischmann, Rudolf—D2
Forsyth, Peter A.—J3
Fowler, W. A.—K2
Freistadt, Hans—C7
Frost, R. T.—R6
Galbraith, A. R.—S7
Gardner, C. C.—R4
Garlick, Frederick J.—Q1
Garvin, H. L.—E6, E9
Gauger, J.—O8
Ginsberg, Donald M.—S2
Goldberg, M. D.—H9
Gordon, F. J.—B3
Gordon, Hayden S.—J1
Grant, H. L.—O4
Green, T. M.—E6, E9
Greenstein, H. B.—K2
Griffin, James J.—R8
Griffiths, G. M.—H4, N3
Gutmann, F.—F11
Hage, K. D.—O2
Hahn, E. L.—E4, E5, I4, I11
Hall, W. S.—R11
Halpern, I.—H6
Hanks, R. V.—C2
Hanson, Harold P.—L11
Harris, Frank E.—F4
Haskin, D. M.—P3, P4
Hayes, W.—I12
Heath, R. L.—B5
Hebbard, D. F.—H3
Hellwarth, R. W.—S8
Henley, E. M.—H7, H10, N5
Hill, O. H.—L1
Hisatake, Kazuo—B4
Hobson, J. P.—S5
Hogg, B. G.—K5
Hopkins, G. R.—R3
Horen, D. J.—B2
House, L. L.—R6
Hubbs, J. C.—E7, E8
Hutchison, T. S.—S1
Imhof, W. L.—H5
Jacobs, J. A.—O6
Jacobsohn, Boris A.—C3, N6
Jameson, Jr., William J.—F2
Johnson, R. G.—H5
Jones, G.—K6
Jopson, R. C.—B3
Judek, B.—P14
Kaempffer, F. A.—C6
Kavanagh, R. W.—B7
Kellogg, Paul J.—C4
Kenney, R. W.—P10
Kernan, W.—P5
Knapp, E. A.—P10
Knight, J. D.—H8
Knowles, H. B.—N2
Kohman, G. T.—S10
Kretschmar, George G.—L4
Kumar, R. C.—P13, P14
Kunz, P. D.—H10
Kurbatov, J. D.—B4
LaRocca, E. W.—L8
Larson, E. A.—H4
Lauritsen, C. C.—K2
Lauritsen, Thomas—K1
Lawrence, Jr., Samuel C.—L10
Lax, Melvin—Q4
LeBlanc, J. M.—H9
Lee, D. M.—S3
Levitt, L. C.—C1
Levitt, Leonard S.—S6, SP1, SP2
Lew, Hin—M1
Lipworth, E.—E6, E9
Livingston, L.—O11
Lohrmann, E.—P4, P6
Lokken, J. E.—O5
Lugn, Jr., Alvin L.—O10
Madsen, V. A.—H7
Maki, Gilda—E11
Maloy, J. O.—P9
Mann, L. G.—K3
March, R.—P5
Marino, Lawrence L.—E10
Mark, Hans—B3
Marrus, R.—E7
Matz, D.—C6
Maunsell, C. D.—O5
Mayfield, Earle B.—O9
McAfee, K. B.—S10
McDaniel, Boyce D.—G3
McDaniels, D. K.—N5
McEwen, J. G.—P13, P14
Meyerott, R. E.—F6
Miller, Leston W.—N6
Millett, W. E.—K4
Mims, W. B.—I9
Misho, R.—L9
Miskel, J. A.—K3
Mohling, Franz—C3
Montgomery, D. J.—L9
Moore, Richard L.—R1
Nakada, M. P.—R4
Nasmyth, P. W.—O7
Neddermeyer, S. H.—P12
Neilson, G. C.—H11, H12, H13
Nickel, J. C.—L12
Nierenberg, W. A.—E9
Norberg, Richard E.—Q3
Nordberg, M. E.—K2
Nordin, P.—P16
Ogier, W. T.—L12
Olsen, W. C.—K7, K8
Oppenheim, I.—C2
Patterson, A. M.—O3
Perez-Mendez, V.—P10
Peterson, F. L.—N10
Peterson, V. Z.—P8, P9
Phillips, Owen M.—O1
Pickup, E.—P13, P14
Potter, Roy F.—L4, L5, L6
Preiss, I. L.—H2
Radford, H. E.—I6
Rasmussen, John O.—N7
Rayburn, L. A.—R5
Redfield, Alfred G.—M4
Redmond, P. J.—C5
Reppy, J. D.—S3
Rickey, M.—K9
Riley, P. J.—N3
Robben, F. A.—F5
Robertson, L. P.—H4
Robison, P. C.—K9
Rocard, J. M.—I3
Rose, M. E.—P1
Rosen, A.—B6
Ross, Ronald R.—P15
Rosselet, P. E.—P8

Rowe, E. M.—N11
Sample, J. T.—H11, H12, H13
Sandhu, H. S.—I2
Schein, Marcel—P3, P4
Schuman, R. P.—B5
Seagrave, J. D.—R2, R9, R10
Shand, J. A.—O6
Shapiro, S.—E1
Sharpless, Robert—F7
Shenstone, Allen G.—F1
Shook, G. B.—N4
Shugart, Howard A.—E10
Sill, R. C.—S9
Silsbee, Henry B.—E10
Simmons, J. E.—R2, R9, R10
Sood, P. C.—N8, N9
Steinberger, Jack—G5
Stewart, R. W.—O4
Stine, Howard A.—O10
Strelzoff, A. G.—L9
Struve, Otto—J2
Stubbins, Warren Fenton—P11
Swenson, D. A.—N11
Teucher, M. W.—P3, P4, P6
Tinkham, M.—S2
Thompson, William B.—A1
Tobocman, William—D3
Trainor, L. E. H.—N8
Turk, E. H.—B5
Turner, T. E.—O8
Uehling, Edwin A.—E3
Uretsky, J. L.—C5
Vali, V.—O8
van der Ziel, A.—L2, S7
van Vliet, K. M.—L2, S7
Vaughn, F. J.—H5
Wagoner, Cleo B.—O10
Walt, M.—H5
Warren, J. B.—K6, N3
Webb, L. A.—E2
Weber, M. J.—I4
Wegner, H. E.—R11
Wells, D. O.—B2
Wesemeyer, H.—I8
Wetstone, D.—O11
Wheatley, John C.—M3
Whetstone, Jr., Stanley L.—R7
White, B. L.—K7, K8
Wigen, P. E.—I7
Wikner, E. G.—I11
Wild, R. L.—L12
Wilkinson, Denys H.—B1
Williams, John H.—N1
Winocur, J.—E7, E8
Wittenborn, A. F.—L1
Wong, C.—R4
Woodward, William M.—G4
Wright, C. S.—O7
York, C. M.—P5
Young, Robert A.—F7
Yuster, P. H.—I12

Reservations for Vancouver Meeting

To: G. L. Pickard

Department of Physics
University of British Columbia
Vancouver 8, B. C., Canada

Please reserve accommodations for (names)

.....

.....

.....

for nights of August 25 ....., 26 ....., 27 ....., 28 .....

for Women's Residences ($3.00 per night) ..... (no children)

or Fort Camp Dormitory ($2.00 per night) .....

Probable arrival by auto ....., train ....., plane ....., bus ....., boat .....

To: G. L. Pickard

Department of Physics
University of British Columbia
Vancouver 8, B. C., Canada

I expect to attend the dinner of the American Physical Society at seven o'clock on

Wednesday evening, August 27th. My party will comprise ..... persons.

Name .....

Address .....

(If you wish to have your tickets held to the time of the banquet itself, send a cheque made out to the American Physical Society for $3.25 per plate).

Second Announcement of the 1958 Thanksgiving Meeting

The 1958 Thanksgiving Meeting will be held at Chicago, in the buildings of the University of Chicago, on November 28 and 29. The Hotel Windermere, at 1642 East 56th Street, Chicago 37, Illinois, will accommodate our members until its rooms are fully booked, and will place later applicants in neighboring hotels. Deadline for abstracts of contributed papers is September 26. Abstracts are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York.

Preliminary Announcement of the 1958 Winter Meeting in the West

The Winter Meeting of the American Physical Society in the West is to be held at the University of California at Los Angeles on Monday, Tuesday, and Wednesday, December 29, 30, and 31, 1958. The deadline for the contributed papers for this meeting is Friday, October 17, 1958. Abstracts (one page, 200 words) are to be sent **in duplicate** to Professor William A. Nierenberg, Department of Physics, University of California, Berkeley 4, California. The Physics Department will host the meetings, and the sessions will be held in the Chemistry-Geology Building on the campus.

There will be sessions of invited papers on theoretical physics, nuclear physics, controlled fusion, geophysics, and physics of the solid state. There will also be a special one-day working session in high-energy physics oriented primarily to the interests of research workers in this field.

Hotel accommodations within walking distance of the campus are the Claremont Hotel (from $4 single, $7 double, $5 twin beds), and the Dracker Hotel (from $5 single, $6 double, $6 twin beds). The following motor hotels, located on Wilshire Boulevard, Los Angeles 24, are close to the Village and the campus: Hotel Westwood Plaza (from $6 single, $8 double, $8 twin beds), Ritz Wilshire Motor Hotel (from $5 single, $7 double, $7 twin beds), Tropic Palms Hotel (from $5 single, $6 double), Westwood Inn Motor Hotel (from $9 single, $12 twin beds). There are also the Bel-Air Hotel on Stone Canyon Road (from $15.50 single, $18.50 double), Bel Air Sands on Sunset Boulevard (from $13 single, $16 double), Miramar Hotel in Santa Monica (from $8 single, $13 twin), Hilton Hotel in Beverly Hills (from $13 single, $17 twin beds), Surf Rider Inn, Ocean Avenue, Santa Monica (from $8 single, $8 double).

Since the period between the holidays is a very busy season for the hotels and motels, reservations should be made early, **at least one month before the meeting.** Requests for reservations should be sent directly to the hotel or motel.

Visitors may wish to visit Marineland, Knott's Berry Farm, Disneyland, and Catalina while in Southern California.

Preliminary Announcement of the 1959 Annual Meeting

The 1959 Annual Meeting will be held at New York, mainly in the Hotel New Yorker and Manhattan Center, on January 28–31, 1959. The official hotel is the New Yorker (New York 1, New York). Deadline for abstracts of contributed papers is November 14, 1958. Abstracts are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York.

Announcement of the 1958 Meeting of the Division of Fluid Dynamics

The Division of Fluid Dynamics of the American Physical Society will hold its annual meeting at the Hotel San Diego, San Diego, California, Monday, Tuesday, and Wednesday, November 24th, 25th, and 26th. Deadline date for the receipt of abstracts is October 13, 1958. Abstracts of contributed papers of not over 200 words, prepared in accordance with the rules printed in this Bulletin, should be sent in duplicate to the Secretary of the Division, Raymond J. Emrich, Department of Physics, Lehigh University, Bethlehem, Pennsylvania. The headquarters hotel for this meeting will be the Hotel San Diego, San Diego, California. Room reservations should be made individually by writing to Hotel San Diego and mentioning the meeting of the Division of the Society.

MEETINGS AND DEADLINES FOR THE SEASON 1958–1959

Place	*Meeting dates*	*Deadline date*
Vancouver, British Columbia*	August 26–28	past
Chicago	November 28–29	September 26
Los Angeles*	December 29–31	October 17
New York	January 28–31, 1959	November 14
Austin, Texas	March 6–7	January 9
Cambridge, Massachusetts	March 30, 31, April 1	January 16
Washington, D. C.	April 30, May 1–2	February 20
Milwaukee, Wisconsin	June 18–20	to be decided
Hawaii	August 27–29	to be decided

* Abstracts for the Los Angeles and Hawaii meetings are to be sent to W. A. NIERENBERG, University of California, Berkeley 4, California, and must reach his office not later than the corresponding deadline date.

Abstracts for the other meetings listed above are to be sent to KARL K. DARROW, American Physical Society, Columbia University, New York 27, New York, and must reach his office not later than the corresponding deadline date. Take note that abstracts mailed the day before deadline day often fail to arrive in time: the last postal delivery of the day usually comes to our office before 2 P.M. Allow at least two days for abstracts sent by airmail from points east of the Mississippi, and longer for those sent from farther west. To avoid chance of confusion, please do not send an abstract for any meeting until the deadline date of the previous meeting is at least five days past. *The privilege of contributing papers to meetings of the American Physical Society is restricted to the members of the Society and to nonmembers whose papers are sponsored by members.*

RULES AND INSTRUCTIONS FOR THE PREPARATION OF ABSTRACTS

The Council has ordered that abstracts shall be not longer than two hundred (200) words or the equivalent thereof. In reckoning equivalence, a footnote is equated to ten words; each line in a table to ten words; a "display" formula—one that requires a line to itself—is an expensive luxury equated to forty words.

Two copies of each abstract must be sent to the appropriate office. They must be typewritten; one must be an original, the other may be an original or a carbon copy. Carbon copies will not be accepted in lieu of originals: they smear. *Abstracts must be double-spaced:* single-spaced manuscripts are too crowded to permit the editorial markings to be made with ease and clearness. Each abstract must be confined to a single page: if it is too long for a single page it is too long to be printed. *If we receive an abstract typed on two pages, we print only its first page.* Write each abstract as a single paragraph: the suppression of paragraphs costs time and labor to the editors. Do not use very thin paper; a sheet of very thin paper may cause extraordinary trouble when mixed with sheets of reasonable thickness. Look at the abstracts in this *Bulletin* to see how the title of the paper and the name of the author are to be arranged, and follow the example. Issues of the *Bulletin* are always appreciably delayed because the editors have to do what the authors should have done.

Remember the rule of the Council that, if an author submits more than one abstract, all but one must go onto the Supplementary Programme. In enforcing this rule, an abstract is credited to the author whose name appears first in the by-line.

It now becomes an expensive business to make any change in an abstract, even the smallest, after the abstract has gone to press. By order of our Council "A change in an abstract will be permitted only at the discretion of the Secretary or his deputy, and only if TEN DOLLARS is enclosed with the letter in which the change is requested." As heretofore, an abstract will not be withdrawn from proof unless the asker sends ten dollars with his request.

Report of the Nominating Committee

The 1958 Nominating Committee of the American Physical Society has nominated to various offices of the Society, for terms beginning at the end of the 1959 Annual Meeting, the following candidates:

To the Presidency: G. E. UHLENBECK
To the Vice-Presidency: V. F. WEISSKOPF
To the Secretaryship: K. K. DARROW
To the Treasurership: S. L. QUIMBY
To the Managing Editorship: S. A. GOUDSMIT
To (two) posts on the Council: HARVEY BROOKS, E. C. CREUTZ, L. J. HAWORTH, SIDNEY KRASIK, RAGNAR ROLLEFSON, C. H. TOWNES.

To (six) posts on the Board of Editors, with special assignment to *The Physical Review:* S. C. BROWN, K. A. BRUECKNER, FRANK HERMAN, G. E. PAKE, JAMES L. TUCK, G. H. VINEYARD.

To (two) posts on the Board of Editors, with special assignment to *Reviews of Modern Physics:* JOHN BARDEEN, ROBERT HOFSTADTER.

Of the foregoing, Messrs. Uhlenbeck, Darrow, Quimby, and Goudsmit were nominated also by more than the requisite number of votes of the membership-at-large of the Society.

Eligibility and Election to Fellowship

At the request of the Advisory Committee on Fellowship Nominations, the parts of the Constitution of the American Physical Society which define eligibility to Fellowship and prescribe the manner of election to Fellowship are here reprinted for the convenience of readers of this Bulletin.

Article III, Section 2 of the Constitution. There shall be elected to Fellowship only such persons as have contributed to the advancement of physics by independent, original research, or have rendered some other special service to the cause of the science which is considered equivalent to such investigations. The fulfillment of these qualifications shall normally be determined by an examination of the published works of the candidate.

Article IV, Section 1 of the Constitution. For the election of a new Fellow . . . of the Society, or for the transfer of a Member to Fellowship, a nomination in due form, signed by two Fellows or Members, shall be presented at a meeting of the Council, and at a meeting of the Council occurring at least two weeks later the person named in such nomination shall receive the favorable ballots of a majority of the Councillors present. . . .

(Be it noted that it is the practice of the Council to elect to Fellowship only persons who reside in North America or the insular possessions of the United States. This is primarily because there are many countries in which it is not easy for a person to procure even the amount of foreign exchange necessary for payment of Membership dues, let alone the higher dues appropriate to Fellowship.)

Proceedings of the American Physical Society

Minutes of the 1958 Spring Meeting Held at Washington, May 1–2–3, 1958

The 1958 Washington (or Spring) Meeting of the American Physical Society was held on Thursday, Friday, and Saturday, May first, second, and third. Our scientific sessions were located in the Sheraton-Park and Shoreham hotels and in the National Bureau of Standards. All this was in consonance with our habit of recent years; but it must not be assumed that this congenial habit will be permanent, for we are in trouble arising from the fact that our customary meeting time is the most crowded and difficult time of all the year in Washington. It is doubtful whether we should any longer be able to hold these Washington meetings at all were it not for the extremely able Chairman of our Local Committee R. D. Huntoon, his principal aide W. R. Tilley, and his secretary Mrs. Florence Sharkey, our debt to whom has long passed the highest level at which there are words to express it. Other members of the Local Committee were D. F. Bleil, W. C. Hall, A. L. Mahan, J. H. McMillen, S. F. Singer, L. Slack, and G. Temmer. We thank them all, and we thank Mrs. Carl L. Frederick for arranging the ladies' programme. Eugene Kone of the American Institute of Physics handled press relations. The weather also collaborated; even though the whole of the meeting was in May there was never insufferable heat.

The registration came to 1911—markedly over last year's figure (1732) but nowhere near the altitudes which have become the rule at our New York meetings (over 3300). The most heavily attended of the sessions were the one addressed by C. N. Yang and T. D. Lee, on Friday morning, and the symposium entitled "thermonuclear enterprises" on Friday afternoon. In the latter there seemed to be a perfect match in number between chairs and listeners in the big Sheraton Hall (one wishes this were always so) while in the former the crowd was almost as large. One symposium on Thursday morning was arranged as a feature of the "photonuclear conference" which had begun the day before at the National Bureau of Standards. Owing to this and other particular reasons there were no fewer than eight sessions on Thursday morning; there were seven on Thursday afternoon, seven also on Friday both morning and afternoon, and six on Saturday both morning and afternoon.

The banquet was held on Friday evening in the Terrace Room of the Shoreham Hotel, with an attendance of 290, somewhat better than—that is, not quite so deplorably low as—the attendance of last year. Notable after-dinner speeches were delivered by Wallace R. Brode and Herbert York.

The Nominating Committee met on Thursday: its report will be found on page 347 of this Bulletin.

The Council met on the Wednesday preceding the meeting of the Society. Subjoined are the names of the 122 candidates elected to Membership and the 21 elected to Fellowship in the Society.

Karl K. Darrow, *Secretary*

Elected to Fellowship on April 30, 1958: Harry C. Allen, Jr., Ernest Ambler, Zoltan L. Bay, Felix H. Boehm, Rodney Lee Cool, Raymond Davis, Vernon H. Dibeler, Alan D. Franklin, Joe L. Franklin, H. P. R. Frederikse, R. H. Good, Jr., Charles M. Herzfeld, John D. Hoffman, Ralph P. Hudson, Herbert Jehle, A. Turner McPherson, Robert S. Marvin, Joseph W. Motz, Howard H. Seliger, Andrew W. Sunyar, M. Z. v. Krzywoblocki.

Elected to Membership on April 30, 1958: *Lee S. Anthony, *Vincent D. Arp, Roland J. Barriault, James E. Bauerle, *Robert W. Bercaw, Herbert L. Bresnick, *Saul Broida, Rodney D. Brown, III, James N. Bryden, *Richard A. Carrigan, *Joseph E. Carroll, Ralph H. Condit, Leo Davis, Robert C. Dean, Jr., *Donald A. DeLise, Earle F. Ditzel, *Herman R. Djie, *D. W. Dorn, Maurice E. Drougard, *John N. Dyer, *Felix M. Eeger, Charles Eisenhauer, *Mohamed A. El-Bayoumi, *W. Bruce Ewbank, Harvey Fields, *Walter L. Foxworth, Mitchell Gilbert, *Marshall L. Ginter, Ahmad Ali Golestaneh, Ralph C. Golike, Paul E. Gordon, *Robert E. Green, Jr., Edward K. Greenwald, Niels J. Hansen, Robert C. Hansen, William B. Hanson, Don S. Harmer, Gordon R. Harrison, Hisanao Hatakeyama, Frederick R. Hays, *Robert N. Hill, Richard Horowitz, C. C. Hsiao, *Richard M. Ikeda, *Phillip J. Joseph, *Michael D. Kaizen, *John E. Keller, Martin J. Kelly, Stephen G. Kovacs, Gerald E. Lamale, *Neal L. Laurance, Po Lee, Thomas H. Lee, *Rolf E. Lindquist, *Ralph A. Llewellyn, Jr., Harry Lobel, *Lawrence W. Lock, *Georges W. London, Michael S. Macrakis, John P. Magos, Rochard C. McCall, *John C. McCullen, * Kenneth S. Mendelson, *Allen H. Miller, *Wesley E. Moore, Walter S. Moos, Vincent O. Mowery, Irving Nadelhaft, Leo Nedelsky, *Richard G. Netzel, Leo J. Neuringer, Weymar Z. Osborne, Bergmann Otto, Samuel J. Ovenshine, Paul M. Pan, *Paul Penfield, Jr., *James G. Pengra, John E. Pippin, *Spiros G. Plentzas, Charles H. Pruett, Hubert F. Quinn, *Luis Quinones-Rodriguez, *Lajos Rimai, Victor H. Ritz, *George P. Rodriguez, *Marvin L. Roush, Hans M. Ruppel, Nathan Rynn, Carleton E. Sawyer, Joseph H. Scanlon, *Hugo Schmidt, *Howard J. Schnitzer, Robert A. Sehr, Milton R. Seiler, David K. Seto, Y. T. Sihvonen, Mathew E. Sikorski, Charles A. Simmons, Jag Jeet Singh, Carleton C. Smith, Gordon R. Spencer, *Robert C. Stabler, *Ira Z. Steinberg, Harold S. Story, Roy F. Stratton, Jr., Donald R. Taft, *Louis A. Tamburino, Robert L. Tedesco, Theodore C. Tjader, Joseph T. Vanderslice, Thomas R. Vogt, Arthur Wachowski, *John A. Wamsley, *Robert B. Weinberg, Jasper A. Welch, Jr., Forrest G. West, Stanley L. Whitcher, *William Williamson, Jr., *Donald J. Young.

* Student.

Errata Pertaining to the Foretext and Abstracts B11, EA1, NA9, S7, V10, and VA8 of the 1958 Washington Bulletin (Series II, Volume 3, No. 3)

Page 159, second paragraph, next to last line, change the first word, "Author," to "Arthur."

B11, by N. Nath, D. M. Van Patter, M. A. Rothman, and E. A. Mandeville. In lines 3, 10, and 14, "0.764" should read "0.75±0.01." In lines 4, 11, and 15, "0.977" should read "0.96±0.01." The second reference, "† On leave of absence from the University of Delhi, India." should read "† Permanent adress, Delhi, India."

EA1, by Leonard S. Levitt. In line 3, "$(n_3+\frac{3}{2}n_2-9/2n_1)/\alpha$" should read "$(n_3+\frac{3}{2}n_2-\frac{3}{2}n_1)/\alpha$."

NA9, by J. Ballman, R. R. Crittenden, J. H. Scandrett, W. D. Shephard, and W. D. Walker. In lines 8, "14" should read "9" and "2.5" should read "6."

S7, by S. S. Malik, Narenda Nath, and C. E. Mandeville. In line 1, "Narenda Nath" should read "N. Nath." In the index, p. 236, "Narenda Nath" should read "N. Nath."

V10, by H. Nichols. In line 1, "H. Nichols" should read "W. H. Nichols." In line 21, "$g_S=0.7$" should read "$g_S=1.6$" and "$g_W=2\times10^{-7}$" should read "$g_W=5\times10^{-8}$." In the index, p. 236, "Nichols, H." should read "Nichols, W. H."

VA8, by H. J. Krusemeyer. In line 4, "crystals" should read "crystals.[1]" In line 22, "Thomas" should read "Thomas.[2]" The following references should be added: [1] R. J. Collins and D. G. Thomas (to be published). [2] R. J. Collins and D. G. Thomas, Bull. Am. Phys. Soc. Ser. II, **2**, 271 (1957).

Minutes of the Spring Meeting of the Ohio Section of the American Physical Society Held at the University of Akron, Akron, Ohio, on April 11–12, 1958

THE regular Spring Meeting of the Ohio Section of The American Physical Society was held in joint session with the Section E, Physics and Astronomy, Ohio Academy of Science, at the University of Akron, Akron, Ohio, on Friday and Saturday, April 11–12, 1958.

Friday morning was used in viewing and helping judge the Science Day projects submitted by the High School students of Ohio. There were about 270 projects in the category of physics which had survived the district competition. The men of the Section served as judges to help in rating these projects.

The Friday afternoon program consisted of Invited Papers on "Physics in the Rubber Industry," as follows:

Fatigue of Rubber. C. S. Wilkinson and S. D. Gehman, *Goodyear Tire and Rubber Company.*

High-Speed Photography in the Rubber Industry. G. L. Hall and F. S. Conant, *The Firestone Tire and Rubber Company.*

Chain Scission in the Oxidation of Natural Rubber Vulcanizates. A. G. Veith, *The B. F. Goodrich Research Center.*

Reinforcement of Elastomers by Solid Particles. J. P. Berry, *Institute of Rubber Research, University of Akron, Akron, Ohio.*

Saturday morning was devoted to six contributed papers and a visit to the University of Akron reactor. One paper, by R. E. Johnson and E. L. Jossem, "Studies of Solid Surfaces by X-Ray Total Reflections," did not have an abstract. A second paper discussed the University of Akron reactor and its possible uses, and also did not have an abstract. The four abstracts of new material follow these minutes.

This being the annual meeting, the following officers were chosen for the year 1958–1959: *Chairman,* Howard N. Maxwell, Ohio Wesleyan University, Delaware, Ohio; *Vice-Chairman,* M. Eugene Merchant, Cincinnati Milling Machine Company, Cincinnati, Ohio; *Secretary-Treasurer,* Leon E. Smith, Denison University, Granville, Ohio.

Following the meeting, the Ohio Section had luncheon at the University Club, at which time Dr. Bowen C. Dees spoke to the members on "Federal Program for Improving Science Education."

Leon E. Smith, *Secretary*
Ohio Section of the
American Physical Society
Denison University
Granville, Ohio

Proton Magnetic Resonance in Hydrated Single Crystals.* J. W. McGrath, A. A. Silvidi, and J. C. Carroll, *Kent State University, Kent, Ohio.*—The proton-proton separations in a series of hydrated crystals are being remeasured since reported values vary by more than experimental error. If this variation is real an explanation will be sought. We are using a slightly modified Pound-Watkins NMR spectrometer.[1] Parameters are: $RF=25$ mc, $H=5870$ gauss, modulation amplitude = 1 gauss, modulation frequency = 280 cps and sweep speed = 0.02 gauss/sec. Signal to noise ratios for crystals are about 30. The Pake technique[2] is being used. For gypsum the measured value of the p-p separation is 1.58±0.02 A. The p-p axes lie in the ab plane (±10°) and they make angles of 36±4° and 45±4° with the axis. These values agree well with those of Pake.[2] In lithium sulfate, an orientation-independent shift of +3 gauss appears in the Pake curve. This is essentially in agreement with Pake.[2] The origin and effects of this shift are being studied.

* Partially supported by the U. S. Air Force through the Air Force Office of Scientific Research under contract.
[1] G. D. Watkins, Ph.D. thesis, Harvard (1952).
[2] G. E. Pake, J. Chem. Phys. **16**, 327 (1948).
[3] G. E. Pake, Ph.D. thesis, Harvard (1948).

Steady-State Space Charge between Parallel Plates. Philip A. Macklin, *Miami University, Oxford, Ohio.*—Most texts in beginning electronics indicate that the space charge limited

current reaching the plate of a diode is independent of cathode temperature (Langmuir-Child equation). As is well known,[1] this is strictly true only for zero initial electron velocities. In an attempt to find an analytically tractable solution which would give the student some insight into the departures from ideality caused by nonzero initial velocities, the case of the parallel plate diode with nonzero, but unique, initial velocity is developed. Variation of plate current with injected current for fixed plate voltage, variation of plate current with plate voltage for fixed injection current and variation of virtual cathode location with fraction of injected current transmitted for fixed injection current are discussed for this special case. The assistance of Mr. Willis W. Myers[2] in this work is gratefully acknowledged.

[1] Fay, Samuel, and Shockley, Bell System Tech. J. 17, 49 (1938).
[2] Now at Purdue University, Lafayette, Indiana.

Nuclear Orientation of Co^{56} and Co^{60}.* DAVID F. GRIFFING, *Miami University, Oxford, Ohio.*—Radioactive Co^{56} and Co^{60} were grown in the same single crystals of (0.8 Cu:0.2 Zn: Trace-Co)$K_2(SO_4)_2 \cdot 6H_2O$ and cooled to about 13 millidegrees Kelvin by a two-stage adiabatic demagnetization technique. The gamma radiation from these two cobalt isotopes was detected with a scintillation counter used in conjunction with a single channel analyzer. The angular distribution of this composite gamma spectrum was measured at all energies above 1 Mev as a function of the susceptibility of the crystals. The susceptibility data were correlated with the absolute temperature of the crystals by using the measurements on the angular distribution of the Co^{60} gamma rays together with the known decay scheme, spin, and magnetic moment of Co^{60}. The angular distributions of the Co^{56} gamma rays were used to obtain information about the parent nucleus and its decay. The analysis of this complex gamma spectrum and of the associated warmup data will be discussed, and preliminary results will be presented.

* Work supported by joint program of the Office of Naval Research and of the U. S. Atomic Energy Commission.

Poor Man's Minitrack. RAY JURGENS AND CARL TRIVETT, *Ohio University, Athens, Ohio.*—The signals from the two Russian satellites, 1957α and 1957β, have been monitored using simple low-cost equipment. The equipment consisted of two half-wave dipoles, hybrid function, Hallicrafters SX-25 receiver, magnetic tape recorder, Honeywell Brown Electronic recorder and a BC-221 frequency meter. Doppler shift curves were plotted from the tape recorder by the use of an oscilloscope and an audio generator. From these the perpendicular distance and velocity were determined. The results show the feasibility of such a project and that it is within the budget of most small colleges. The results and problems will be discussed.

The American Physical Society

OFFICERS OF THE SOCIETY FOR 1958

President	J. W. BEAMS	University of Virginia
Vice-President	G. E. UHLENBECK	University of Michigan
Secretary	K. K. DARROW	Bell Telephone Laboratories (*retired*) (Office at Columbia University)
Treasurer	S. L. QUIMBY	Columbia University
Managing Editor	S. A. GOUDSMIT	Brookhaven National Laboratory

Past Presidents now on Council: W. F. G. Swann, R. T. Birge, E. P. Wigner, and H. D. Smyth.

Elected Members now on Council: F. Seitz, A. M. Weinberg, S. K. Allison, N. F. Ramsey, Walker Bleakney, W. K. H. Panofsky, W. A. Fowler, and Charles Kittel.

Local Secretary for the Pacific Coast	W. A. NIERENBERG	University of California, Berkeley
Deputy Secretary	W. W. HAVENS, JR.	Columbia University

1958 OFFICERS OF THE DIVISION OF ELECTRON PHYSICS

Chairman	M. A. BIONDI	Westinghouse Research Laboratories
Vice-Chairman	W. P. DYKE	Linfield Research Institute
Secretary-Treasurer	V. L. STOUT	General Electric Company

Remaining members of Executive Committee: S. C. BROWN, R. H. GOOD, H. D. HAGSTRUM, E. W. MUELLER, N. L. OLESON, AND E. S. RITTNER

Memoranda

Memoranda

Memoranda

Memoranda

Memoranda

Memoranda